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NOTICE TO CONTRIBUTORS

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RACIAL DIFFERENCES IN SIZE AND GROWTH IN THE NEW ZEALAND SNAPPER

By ALAN R. LONGHURST*

Summary

The snapper is most heavily exploited in New Zealand on the grounds near the centres of population in the north, and subjective evidence suggested that here the stocks were composed of smaller fish than elsewhere.

A preliminary survey of size frequency distribution and growth rates shows that there is, indeed, a progressive decline in the average length of the fish from south to north, but also that the absolute rate of growth is faster in the southern large-fish stocks, while the relative growth rate is similar in both stocks. Snapper may be relatively sedentary, tagging giving no evidence of long migrations, and it is suggested that the differences observed in size and growth, together with differences in relative growth of scales are more likely to be due to local racial differences rather than to the effects of over-exploitation.

INTRODUCTION

The snapper, *Chrysophrys* (= *Pagrus?*) *auratus* Forster, comprises at the present time about 30% by weight of the wet fish landings in New Zealand, the fishery being concentrated mainly on the north and west coasts of the North Island, generally in water shallower than 50 to 60 fathoms. The distribution of the species and its relative importance in the landings is indicated in Fig. 1; along the north coast, from North Cape to East Cape, snapper forms up to 80 to 90% of the total landings at the small ports which draw only on local grounds, dropping to 30 to 61% at Tauranga and Auckland where the fleets are wider ranging and tarakahi (*Cheilodactylus macropterus*) is important in the landings; along the west coast, and in Tasman Bay and Golden Bay, from 30 to 90% of the landings are normally snapper

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except at Kaipara where flounder and mullet predominate; on the east coast, from East Cape to Cook Strait, and on both main coasts of the South Island, snapper rarely form even 5% of the total.

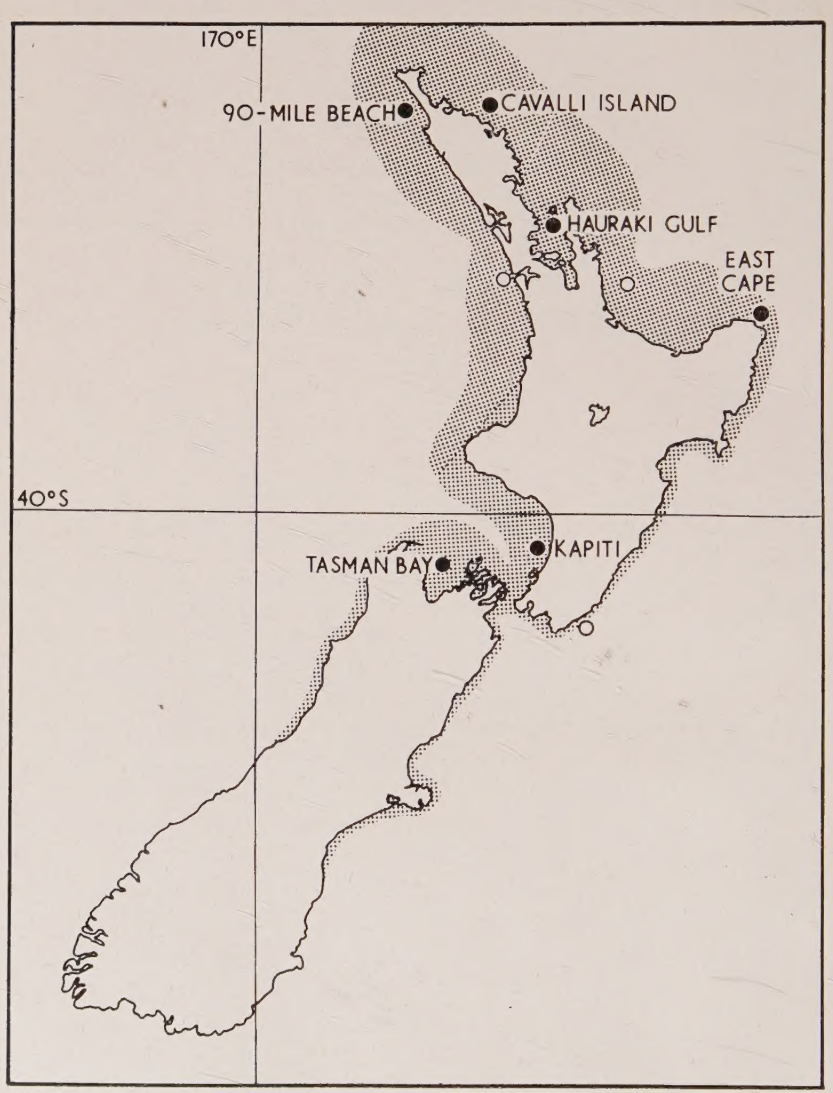

FIG. 1.—The distribution of the snapper fishery in New Zealand waters; the importance of snapper as a proportion of the total wet-fish landings on each stretch of the coast is indicated, diagrammatically, by the width of the stippled zone around the coastline (data from New Zealand Marine Department Reports on Fisheries). Isolated individuals have been recorded from the remainder of the South Island. (Closed circles—main samples for growth rate determinations; open circles—subsidiary samples.)

Snapper are a domestically acceptable fish in New Zealand and are landed whenever they are taken by a fishing vessel, so that it seems possible that the pattern of the fishery corresponds fairly closely with the distributional pattern of the species on the continental shelf. This is to some extent confirmed by the following data derived from the work of the Marine Department's research launch *Ikatere* between 1954 and 1958 (see below),which indicates a very considerable progressive decline in abundance southwards along the east coast of the North Island.

	Total Stns.	Av. depth (fath.)	Total Snapper	Sn/Haul
Hauraki Gulf	100	23·5	29,098	287
Bay of Plenty	42	42·6	1,180	28
East Cape/Hawke Bay	87	42·9	1,189	13
Palliser Bay/C. Campbell	42	40·0	86	2

It is unlikely that there are any major stocks of snapper that now remain completely unexploited although the relative intensity of exploitation of the various stocks is certainly very uneven.

Since the wet fish landings at Auckland are normally more than twice the weight of those at any other New Zealand port, forming up to 25 % of the Dominion total, and since over-exploitation of the Hauraki Gulf stocks of snapper had become a subject for discussion over thirty years ago (Hefford, 1929) it seemed probable that the well known but subjective observations of the relatively small size of the northern fish might have some significance in the context of declining stocks. This paper describes the results of a preliminary survey of this problem which was carried out between January and September 1958.

SIZE FREQUENCY DISTRIBUTION

Data were obtained from the following sources on the present size distribution of the stocks at a number of localities and on changes over a period of years.

(1) Length frequencies recorded on the trawl data sheets of the *Ikatere* for the period 1954-1958. These included measurements of some 30,000 snapper taken with trawls in four main areas—Hauraki Gulf, Bay of Plenty, East Cape/Hawke Bay, and Palliser Bay/Cape Campbell. The gear used during the period included a great variety of mesh sizes, ranging from a 5 in. single manila cod-ed, down to a 1½ in. cotton cod-end cover, and it would be unrealistic to apply corrections to each haul to reduce it to what, in theory, would have been taken at that station by a net of standard mesh—though this might have been possible with a less complex series of samples (Cassie, 1955). How-

ever, the use of different mesh sizes can have little effect on the size frequency distribution above the 100% retention length for the largest mesh used; in the case about 13·5 L_f in. for the 5 in. single manila cod-end.

(2) Market sampling at Nelson, Wellington, and Auckland during 1958. Because of the nature of fish-shed procedure in New Zealand it is not always possible to examine more than a few fish from each landing, but sufficient information was obtained to provide length frequency distributions for Tasman Bay, the Kapiti-Wanganui grounds, 90-mile beach, Cavalli Islands, Hauraki Gulf, and East Cape—covering, approximately, the area untouched by the *Ikatere* data with some overlap along the north coast. Most of the fish are landed in a gutted condition and it was necessary to bulk the two sexes.

(3) Data recorded by Hefford (1929) on length frequency distributions of snapper in the Hauraki Gulf were used for comparison with the more recent data.

All lengths are expressed in inches, and as the fork length (L_f in.), rather than as the standard length; this accords with the practice of the New Zealand Marine Department in recording fish lengths in British standard units and in basing legal minima on the length from snout to the central ray of the caudal fin. To minimize the effect of gear selection only trawl-caught fish are included in this analysis.

The analysis of all these data (Fig. 2) confirmed the supposition that there is a difference in the average size of snapper between the northern and southern portions of the range, this being seen in the progressive shift of the histograms to the right in the figure. There is also a general agreement between the data obtained from the *Ikatere* trawl data sheets and from the commercial landings, except that the former—due to the inclusion of fish taken with experimental fine meshed gear—clearly sampled the smaller-length classes more heavily.

Two of the frequency diagrams derived from the commercial landings (Hauraki Gulf, Tasman Bay) show a distinct bi-modality. This is perhaps explicable if the apparently well known habit of the fish of schooling in two groups is confirmed; the two groups are recognized at Nelson, and probably at other ports, by separate names—the small fish up to about 14 L_f in. being called "bream", the larger fish "snapper". Bream and snapper are said,in general, to occupy Tasman Bay on a mutually exclusive basis so that snapper are found inshore in the winter when bream move into deeper water; a parallel inshore—offshore migration is well known in the Manukau Harbour where it appears to be entirely unconnected with the inshore summer spawning movement of adult fish which may confuse the pattern of migration to a certain extent in Tasman Bay. Since the commercial landings will not represent a randomized sample of the snapper population, but will have a strong bias towards larger fish as the boats actively seek those areas occupied by "snapper" but frequently—in default of "snapper"

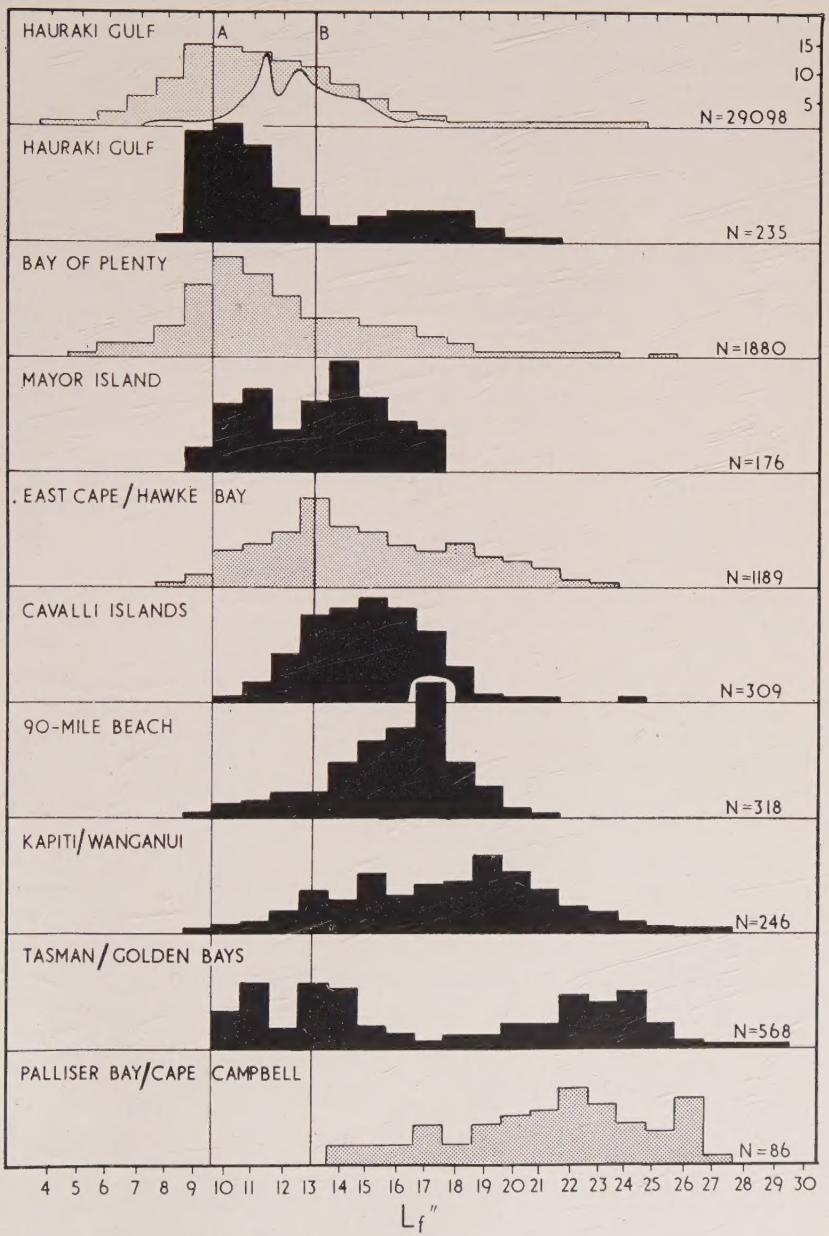

FIG. 2.—Length frequency distribution of snapper from the areas sampled. Stippled histograms, *Ikatere* samples 1954-1958; black, fish-shed samples, 1958. (A—10 in. legal minimal length for commercial landings; B—100% retention level for 5 in. single manila cod-end.)

—have to accept a load of "bream", the modes of the two groups may remain distinct in the size frequency distribution for the commercial catch as a whole.

The form of the size frequency histogram derived from the commercial landings from the Cavalli Islands is interesting and differs markedly from the others in that it approaches a Gaussian curve; these landings were from a virtually virgin ground in 80 to 100 fathoms which had been proved to be workable only with otter trawls a few months previously. It seems certain that such a deep stock of snapper must move inshore during the summer to spawn, for Cassie (1956a) found the limiting temperature for spawning in the species to be at about 18° C, a temperature which could be attained only in the surface waters or close inshore; the occurrence in the Hauraki Gulf in early summer of spawning shoals of school-fish notable for their uniformity of size, silvery coloration, and relatively unworn teeth (compared with the normal Hauraki Gulf snapper, which includes in its diet a proportion of molluscs) leads to the hypothesis that the school-fish may not, in fact, be an aggregation of a relatively few year classes from the Gulf area to spawn, but may represent an onshore migration of a population similar in character to that from the deep Cavalli Islands grounds.

It is unfortunate for the purposes of this investigation that since the 1920's, when large numbers of snapper were measured from the Auckland landings there has been a very considerable change of emphasis from the Danish seine to the otter trawl in the Auckland fleet. However, Hefford (1929) did record the lengths of 609 trawl-caught snapper from the Hauraki Gulf and the relationship between their length frequency distribution and that of fish taken from the same area today is shown in Fig. 2A; there is no indication that significantly larger fish were being taken in this area thirty years ago.

GROWTH RATE DETERMINATIONS

Cassie (1956b), working on the growth rate of Hauraki Gulf snapper, found that the length frequency technique was to be preferred to that of scale reading when the research launch was available for the use of fine meshed cod-end covers, and when only the first few years of life were important. He did, however, find scales from this region workable, if not entirely satisfactory, and in addition recorded and illustrated the extraordinarily clear annuli to be found on the scales of fish from Tasman Bay.

In a regional work of wide geographical coverage such as the present investigation it is not possible with present resources to work entirely with material collected by fine-mesh gear, paticularly for the purpose of the research, and it was decided, in consequence, to place the emphasis in the growth rate studies on the scale technique. This enabled data on growth rates to be collected at the various fish-sheds at the same time as the length frequency data were assembled. It was hoped that

it would be possible to use a back-calculation technique so that scales from, for instance, a single box of fish would give adequate data to construct a growth curve for the population from which they were drawn; an investigation of the allometric constants showed immediately that the growth of the scales was far from isometric, and that a complex allometric relationship between scale and fish growth rates obtained (see below).

Attempts were made to formulate techniques for correcting the errors introduced into the back calculation of intermediate lengths by the allometric relationship but, in the time available for the investigation, these were not satisfactory; growth rates presented here are therefore based entirely on the age-length determination made on individual fish.

Scale reading proved to be relatively satisfactory, and there is a very distinct regional, or racial, difference in the scales from north to south. From Tasman Bay and Golden Bay in the south the great majority are as unambiguous as the one illustrated by Cassie (1956b), and scales with even fourteen or fifteen annuli are read with ease. Scales from the Kapiti/Wanganui populations are similar but include a higher proportion that are read only with difficulty, and there is a tendency in older fish for thickening and vacuolation in the scales to obscure the annuli; scales from north coast are the least satisfactory of interpretation and include many that are not readable. However, even here scales from fish up to five or six years of age are generally interpretable without ambiguity.

Determination of age from annulus counts is relatively simple in the snapper where both spawning and annulus formation (Cassie, 1956b) occur during the summer. Growth throughout the year will not be uniform but there is at present no data on seasonal growth rates in this species; for the purposes of this investigation, therefore, uniform growth had to be assumed and the year divided into calendar quarters from a statutory birthday on 1 January. Age in years is calculated by the number of completed annuli with the addition of a fraction relevant to the quarter in which the sample was taken. Thus, a 3 + fish taken in March is assumed to have completed 3·25 years of growth.

The actual spawning date of the stock in any locality appears to be extremely flexible, though it generally occurs during November, December, or January; ripe fish *may* be found as early as September or as late as March. For this reason the period of active growth during the first year of life may vary somewhat from the normal and this is reflected in the position on the scale of the first annulus—and consequently in the area of the central field—in a proportion of fish, and has caused confusion in the interpretation of scales.

Two variations of the first annulus may be recognized: in most fish (Fig. 3a) the annulus is small, so that the measurement along the central radius from the focus to annulus 1 is less than the spacing be-

tween annuli 1 and 2; in a smaller number of fish, annulus 1 and the central field are very much enlarged (Fig. 3b) so that the spacing between annuli 1 and 2 is smaller than either the radius of the central field or, in some instances, the spacing between annuli 2 and 3.

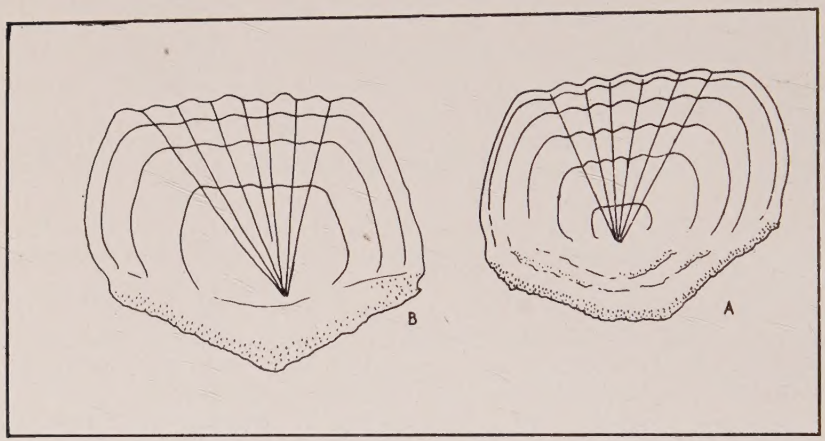

FIG. 3.—Camera-lucida tracings of snapper scales; A—Tasman Bay with 5 annuli, small central field; B—Kapiti grounds with 3 annuli, large central field.

A sample of 36 fish from the Kapiti Grounds included 24 of type A, 12 of type B. In a second from the same area there were 16 of type A, 6 of type B. In these samples agreement between the growth rates of type A and type B fish can only be got if the small inner and the large inner respectively are assumed to be the annulus formed at the end of the first year's growth. In older fish in which the central region of the scale tends to become opaque and vacuolated the presence or absence of type A first annuli is not readily determined and resource must be made to the relative spacing of the next two annuli—2 and 3, or 1 and 2—according to the interpretation of the scale type.

From the results of age-length determination it is possible to construct a growth curve which will represent the mean growth of the population during the periods for which there are recorded annuli, and which will be subject to an uncalculable bias due to year-to-year fluctuations in the growth rate which will, in turn, be influenced by the relative numbers of each year-class in the population. The results of 654 such age-length determinations from six areas are shown in Table 1; the growth rate for the Hauraki Gulf population between 1948 and 1958 calculated by this means does not diverge greatly from that determined by the length frequency method on a further sample of 652 fish taken in the Gulf (Tiri-tiri Island, March 1958) which were

mainly 1+, 2+, and 3+ fish, and is also in good agreement with that determined by Cassie (1955) on the Gulf stock by length frequencies. Comparative results are tabulated below:

Years	1	2	3	4
Cassie (1955)	4·00	7·00	9·00	10·50
Tiri-tiri 1958	4·00	6·80	9·00	—
Scale reading 1958 (Fig. 5)	3·75	7·10	9·30	11·20

The growth rates determined for the six areas covered by Table 1 appear to fall into two groups divided geographically by North Cape: to the east, along the north coast, the growth rate appears to be similar to that of the Hauraki Gulf population, while southwards along the wes coast it is higher. This is shown graphically in Fig. 4 which illustartes the sharpness of the division at North Cape; two samples, those from 90-mile beach and from the Cavalli Islands, abouty forty miles on either side of the cape, show no tendency to a contiguity of points in the graph, though the samples are contiguous geographically.

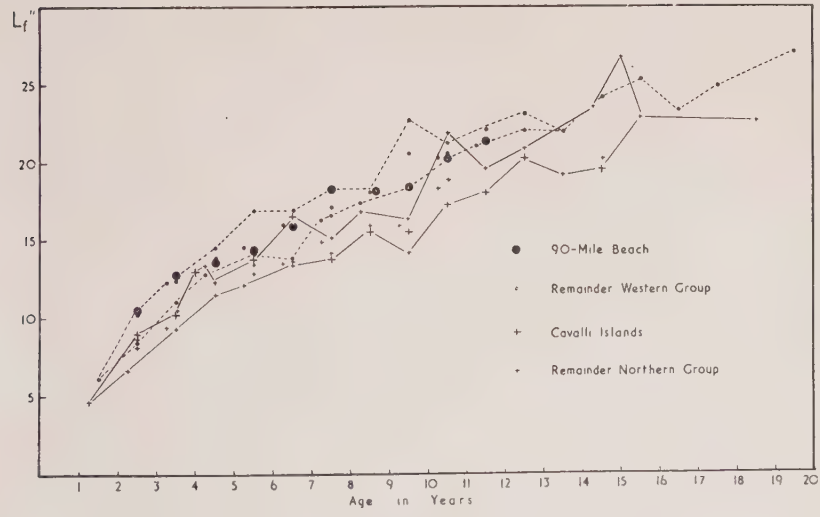

FIG. 4.—Growth rate of snapper; division into eastern and western growth-zones meeting at North Cape. To show that the two areas (90-mile beach, Cavalli Islands) adjacent to North Cape show no tendency to trend together.

In addition to the six major samples, scales were collected from three further areas but neither the numbers in each sample nor the range in fish size is sufficient to construct an adequate growth curve in these cases; however, it is possible from a simple age-length regression of the

individual fish to show that the results do not conflict with those of the main samples—from Cook Strait and Kaipara Bar the fish fall clearly within the range of the western, fast-growth, group, while from Mayor Island in the Bay of Plenty they agree with the northern slow-growth group.

Despite the very considerable difference in absolute growth rate (or in the absolute values of the annual increments) between the northern and the western fish, there is some evidence that the growth rates of the two groups may be similar when calculated on a relative (% incremental) basis; thus, Fig. 5 shows a comparison between the rates of growth calculated by the two methods for those areas from which the most satisfactory data were obtained, and it is clear that the percentage increment method gives very similar figures for the two areas. This finding appears to direct attention towards the relative sizes of the eggs and larval forms at hatching between the two groups as a proximate factor in determining the differences in size of adults of similar ages.

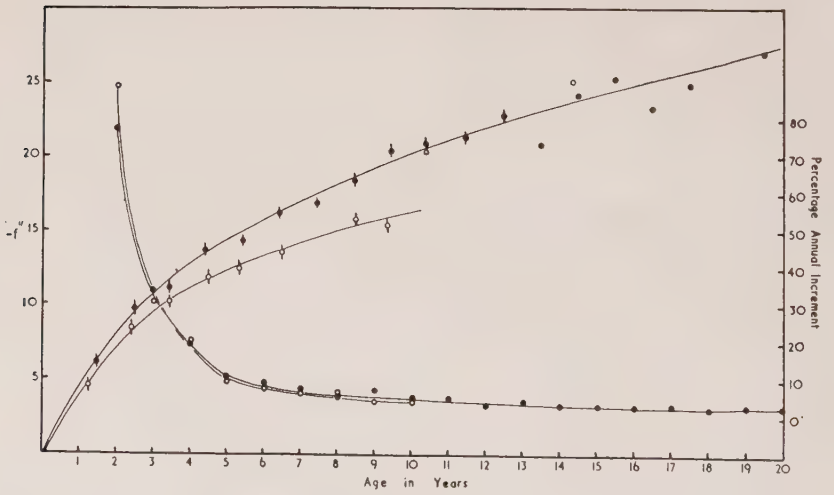

FIG. 5.—Absolute increase in length annually (A) compared with percentage annual increment (B) for samples from Kapiti/Tasman (closed circles) and the Hauraki Gulf (open circles). A vertical stroke through the symbols indicates a sample of more than 5 fish, e.g., those for which standard deviations are given in Table 1. The values on which B is based are data derived directly from the two fitted curves of A.

DISCUSSION

The racial, or regional, differences that have been demonstrated for size and growth rate will probably prove to be accompanied by comparable differences in the meristic characters usually associated with

TABLE 1.—Absolute Growth Rates Calculated from Age/Length Determinations for the Six Major Samples.

Age	Tasman Bay			Kapiti-Wanganui			90-mile beach			Cavalli Island			Hauraki Gulf			East Cape		
(years)	N	$\bar{X}$	±	N	$\bar{X}$	±	N	$\bar{X}$	±	N	$\bar{X}$	±	N	$\bar{X}$	±	N	$\bar{X}$	±
1·25	—	—	—	—	—	—	—	—	—	—	—	—	5	4·60	0·43	—	—	—
1·50	6	6·18	0·11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2·25	—	—	—	—	—	—	—	—	—	—	—	—	5	6·70	0·40	—	—	—
2·50	3	8·40	—	6	10·21	1·15	10	10·40	0·95	7	8·91	1·59	10	8·92	0·38	7	8·05	0·53
3·25	—	—	—	6	12·33	1·45	—	—	—	—	—	—	5	9·44	0·67	—	—	—
3·50	37	11·02	0·51	6	12·48	0·93	12	12·48	1·05	2	10·20	—	39	10·47	0·88	22	9·39	1·24
4·25	—	—	—	3	12·80	—	—	—	—	—	—	—	1	13·40	—	—	—	—
4·50	2	14·50	—	4	13·87	—	12	13·74	2·23	1	13·00	—	11	11·50	0·84	10	12·32	1·17
5·25	—	—	—	7	14·58	1·45	—	—	—	—	—	—	9	12·05	1·27	—	—	—
5·50	47	14·02	1·02	4	16·90	—	10	14·43	1·16	4	13·75	—	8	12·81	1·63	6	13·75	1·51
6·25	—	—	—	5	15·90	1·37	—	—	—	—	—	—	1	13·50	—	—	—	—
6·50	2	13·80	—	10	16·90	2·97	8	15·93	1·05	8	16·85	0·55	14	13·50	2·05	11	13·60	1·32
7·25	—	—	—	8	16·62	2·20	—	—	—	—	—	—	4	14·90	—	—	—	—
7·50	77	16·66	1·63	12	17·10	1·59	14	18·34	1·55	7	13·60	1·05	5	14·05	—	5	15·14	1·09
8·25	—	—	—	4	17·37	—	—	—	—	—	—	—	1	16·80	—	—	—	—
8·50	4	18·27	—	10	18·43	1·56	10	18·25	1·28	11	15·69	1·33	17	15·75	1·56	3	15·73	—
9·25	—	—	—	—	—	—	—	—	—	—	—	—	2	15·90	—	—	—	—
9·50	1	22·27	—	12	20·65	1·34	4	19·40	—	9	15·34	1·41	2	16·30	—	2	14·10	—
10·25	—	—	—	2	20·25	—	—	—	—	—	—	—	1	18·25	—	—	—	—
10·50	5	21·24	4·23	9	20·54	1·51	1	20·40	—	8	17·05	0·61	2	21·80	—	9	18·79	2·40
11·25	—	—	—	1	21·00	—	—	—	—	—	—	—	—	—	—	—	—	—
11·50	3	22·13	—	9	21·11	1·54	1	21·20	—	2	17·85	—	—	—	—	7	19·50	1·38
12·50	7	23·11	6·08	3	22·00	—	—	—	—	5	20·18	1·21	—	—	—	4	20·85	—
13·50	2	20·90	—	—	—	—	—	—	—	—	—	—	—	—	—	5	19·22	1·70
14·25	—	—	—	—	—	—	—	—	—	—	—	—	1	23·60	—	—	—	—
14·50	3	24·20	—	—	—	—	—	—	—	1	19·50	—	1	26·70	—	7	20·21	1·56
15·50	2	25·25	—	—	—	—	—	—	—	—	—	—	—	—	—	2	22·80	—
16·50	2	23·35	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17·50	2	24·85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18·50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	22·60	—
19·50	2	27·00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20·50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
21·50	1	29·20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
N	142			125			82			68			136			101		

racial distinctions in fish. There is an indication of further differences, though not of this type, in the allometric constant for the growth of scales between the Hauraki Gulf and Tasman Bay populations; in both cases the scale/fish regression on a logarithmic base shows a break in slope at a little less than 10 in. after similar, and almost isometric, growth up to that point. Beyond this length the scale become strongly positively allometric and the allometric constants k for the two populations diverge. The values obtained for k were:

	$< 9{\cdot}5\ L_f$ in.	$> 9{\cdot}5\ L_f$ in.
Hauraki Gulf	0·905	1·860
Tasman Bay	0·905	1·590

The recognition of local racial differences in this species is to be expected in an area such as the New Zealand continental shelf, where the hydrographic regime fluctuates rather widely from place to place, and more especially in a fish with the distribution and migration pattern of the snapper. Moreland (1958) recognizes faunistic areas on the New Zealand shelf in the distributions of shore fishes, and two of these may have some relevance in the distribution of snapper: firstly, there is a northern warm-water fauna which occurs only on the north coast of the North Island—just that region in which the northern group of slow growth rate snapper have been recognized—and secondly a more widespread northern fauna which occurs round the coast of the North Island and has its southern boundary broadly in the Cook Strait area, corresponding approximately to the complete range of the snapper. It is probable that both the racial differences in snapper and the distribution of shore fishes will be explicable in terms of the nature and movement of the oceanic water masses that affect the inshore waters; the appearance in summer of warm water along the north coast as a direct derivative of the sub-tropical west central Pacific water mass (Rochford, 1958) may be the limiting factor in some way for the northern group of fish which appear to occur largely, or entirely, on that part of the coast under its influence.

The seasonal inshore-offshore migrations of snapper are so firmly supported by fishermen and those connected with the fishing industry in New Zealand as to leave no doubt that they do occur, and there is some evidence that individuals may return each season to the same inshore grounds; of some 750 snapper tagged by the Marine Department in recent years there have been only 8 recoveries to date, but after periods of liberty varying from 26 days to about 3 years none of these fish has been recovered more than a few miles from the point of release —the extreme case is of a fish released in Whangarei Inlet, Croixelles Harbour in February, 1952, and recovered in the same inlet at the end of March, 1955. Another was taken after a little more than a year off the same beach at which it was released in Torrent Bay, while several in the Hauraki Gulf area have moved over a period of months

less than could be explained by a semi-diurnal movement with tidal streams. It is possible, however, that migration over longer distances occurs in connection with the "school-fish" phenomenon. A tagging project in the Manukau Harbour to determine the fate of emigrating school-fish produced no returns—a result not surprising if, after leaving the harbour, the fish disperse along the west coast where line-fishing is particularly heavy and returns more likely than on the trawl-exploited grounds outside on which bulk handling of fish reduces the probability of returns.

If there is a degree of geographical stability in the stocks, the existence of local races separable morphologically or physiologically is inherently more probable.

From this preliminary and, necessarily, rather superficial survey no evidence has emerged to support the hypothesis being tested, namely that the heavy fishing intensity in the northern parts of the snappers' range is responsible for the small size of the fish there. The evidence that has emerged suggests the contrary. If a stock of fish is depressed in numbers by heavy exploitation, the survivors may be expected to show an increased rate of growth, but in the present investigation there is no evidence that this has occurred. If there were, in addition, a racial difference between the heavily and the lightly exploited stock it is possible, of course, that such an artificial change in the growth rate might be concealed. This note can reach no firm conclusions, but may serve to define the problems, and to provide material on which to base more pertinent questions.

Acknowledgements

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BIOLOGICAL EVALUATION OF ORGANIC POLLUTION OF NEW ZEALAND STREAMS

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Summary

The bottom faunas of polluted New Zealand streams were studied with the object of devising biological criteria for evaluating the extent and severity of organic pollution. The pollution tolerance of various organisms was determined, but this could not be done for all the species encountered. The assemblages of fauna found in stony-bottomed streams show characteristic reactions to pollution. In grossly polluted areas the fauna is comprised largely of tubificid worms and sometimes includes naid worms and certain chironomid larvae. In somewhat less polluted areas, a molluscan fauna is commonly present as well. With still decreasing degrees of pollution, caddis flies and a number of other organisms are able to survive, until finally even the sensitive mayfly group is unaffected. Sand and silt-bottomed streams afford little suitable substrate for the development of some of these organisms and there the effects of pollution are not so clearly reflected.

Seasonal variations affect the evalution of pollution as well as does this environmental limitation. Evaluation can be conducted long after the critical period has passed, but the results are often less clear-cut and more subject to judgment in interpretation than those collected during or shortly after the critical period.

Introduction

A number of streams throughout New Zealand receive organic pollution by wastes from industries such as dairy factories and freezing works, and by domestic sewage (Inter-departmental Committee on Pollution 1952). The effect of discharging large quantities of organic material to streams is to create a series of chemical, physical, and biological changes downstream from the point of entry. Bartsch (1948), Hawkes (1957), and others, have given good general discussions of these changes with particular emphasis on the biological effects. Bacterial decomposition of the putrescible material takes place, with a resultant reduction in the dissolved oxygen content of the stream. The extent and degree of this oxygen reduction can be slight or great depending on the relationship between the strength, or oxygen demand, of the wastes and the self-purification capacity of the stream. This capacity is based on the ability of the stream to supply oxygen to the bacteria for the decomposition of the wastes, and is determined by such factors as the stream flow, temperature, and reaeration through atmospheric and tributary sources and photosynthesis.

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In serious cases of pollution*, the self-purification capacity is completely exceeded and septic zones are formed in which anaerobic decomposition of the wastes takes place, accompanied by the generation of noxious gases such as hydrogen sulphide, methane, and ammonia. As the wastes decompose into harmless endproducts, the stream reaerates itself and finally returns to a normal condition farther downstream, provided there are no further sources of pollution.

These changes cause corresponding changes in the biota of the stream. Those organisms that cannot survive under conditions of pollution disappear, while the less sensitive species frequently become extremely abundant because of the nutrients available to them in the form of organic wastes and of the limitation of inter-specific competition. As recovery from pollution takes place, more and more species are able to survive, until finally the most sensitive organisms reappear in the biota.

Because of this characteristic reaction the biota have been used to evaluate the extent and severity of pollution. Kolkwitz and Marsson (1908, 1909) and Richardson (1928) did early work on this, and since then a number of investigators have used the biota to evaluate pollution. This biological method has a number of advantages over the more usual chemical and physical sampling*. These give accurate data, readily amenable to tabulation and mathematical analysis, but the value of such data in determining the extent of pollution is dependent upon conditions in the stream when they were collected. Samples must be collected under critical conditions, that is, low stream flow, high temperature, and maximum waste discharge, in order to detect the extreme pollutional effects. Such conditions fluctuate widely seasonally and even diurnally, and thus the collection of critical data often entails an intensive sampling programme. This is frequently not feasible, particularly in New Zealand, where personnel are limited and both peak production periods in important polluting industries and critical stream conditions are of short seasonal duration. If the investigator collects water samples a week after the critical conditions have passed, or even an hour after a batch load of wastes has been discharged from a factory, he may detect little evidence of pollution. The biological consequences of the critical conditions, however, remain evident long after the actual conditions have passed.

*The biological method being considered here is distinct from the sampling for coliform bacteria, which is used as a standard procedure in evaluating water quality. The distribution of coliform bacteria in polluted streams is related more to their origin in the organic wastes than to the effect of those wastes upon the environment.

Thus the biological method has the advantage that a general assessment of the degree of pollution can be made without recourse to prolonged sampling programmes, or at times when the chemical and physical evidence of pollution is minimal, or even absent.

The object of this investigation was to study the effects of organic pollution on the biota of New Zealand streams with the aim of devising biological criteria for evaluating the extent and severity of pollution.

Methods

The method of investigation was extensive rather than intensive. A number of polluted streams in widespread localities were examined, sometimes in connection with more detailed investigations, to determine the general biological changes which took place. In some streams which were markedly affected by pollution, biological recovery could be traced downstream. In other cases this could not be done because of lack of time, or adverse weather conditions, or because of a change in the character of the stream, such as entrance into a tidal area, which made it unsuitable for further comparison.

The group of organisms studied was the macroscopic invertebrates or bottom fauna, an arbitrary designation covering organisms such as arthropods, molluscs, and worms, visible to the naked eye. This group has the advantage that it is amenable to study by the ordinary techniques developed by aquatic biologists for sampling streams. Several investigators (Wurtz, 1955; Gaufin and Tarzwell, 1956; Hawkes, 1957) have pointed out an additional advantage of this grouping in that it generally represents organisms with life-histories longer than those of the microscopic forms, many of which can build up enormous populations within short periods and thus it better reflects past environmental conditions. Since the grouping was an arbitrary one, it was not clear-cut with regard to some of the smaller organisms. The small naid worms, in particular, were difficult to detect in samples containing much organic debris. Such small organisms therefore were less reliable for purposes of comparison from sample to sample than were the larger organisms which comprised the bulk of the group.

Samples collected from the streams on which the study initiated were quantitative ones in which the number of organisms per square foot of bottom was determined. A Surber Sampler was used for this purpose or, in the case of a few deep areas on the South Branch, Waimakariri River, a Peterson Dredge (Welch, 1948). As the study progressed it became apparent that the collection of quantitative data was too time-consuming and that it yielded little pertinent additional information over qualitative sampling. Determination of the composition of the fauna rather than actual numbers per square foot was the objective. This qualitative sampling was done with a simple fine-meshed dip net. At first the organisms in qualitative samples were

grouped into the following categories: scarce (S), common (C), abundant (A), very abundant (V). These arbitrary categories were found to be too loose and later samples were grouped as follows: 1 organism (a), 2-3 (b), 4-6 (c), 7-12 (d), 13-24 (e), 25-49 (f), 50-99 (g), 100-199 (h), 200-399 (i), 400 and over (j). In the case of two rivers, the Manawatu and the Oroua, both quantitative data and qualitative data were collected from the same stations.

Samples of visible growths of algae and sewage fungus were collected but these will not be discussed in detail in this paper. They were merely designated as scarce (S), common (C), abundant (A), very abundant (V), or blanketing the bottom (B). This latter term referred only to sewage fungus which sometimes completely covered the stream bottom in thick masses*.

Trout populations in the North Branch, Waimakariri River, and the Northbrook Drain were sampled with the co-operation of Mr A. M. R. Burnet of the Marine Department. At each station sampled, from 100 to 250 yards of stream were examined with an electric fishing machine (Burnet, 1952) and an estimate of the pounds per acre of trout present was made.

Dissolved oxygen determinations were made in the field, using the sodium azide modification of the Winkler method (American Public Health Association, 1955).

The localities of the stream sampled are shown in Figs 1 and 2. The details of sampling and results obtained are presented in Appendix II. Numerous references are made in the text to the data listed in tabular form in Appendix II. To avoid repetition, the table number for each stream is mentioned in the text only the first time that particular stream is discussed.

DISCUSSION

Effects on Fauna

Many of the wide differences in the bottom fauna which occur from station to station in a given stream are due to factors other than pollution, such as variations in the nature of the stream from upstream to downstream, variations from station to station in current velocity and bottom type, and natural statistical variations related to the distribution of the organisms and sampling adequacy. In addition there were seasonal variations in the bottom fauna collected at different times of year. Allen (1951), Percival (1932), and Phillips (1929,

*Sewage fungus is the complex group comprised largely of colonial bacteria, colonial protozoa, and fungi, which is frequently found in polluted areas. The filamentous bacteria, *Sphaerotilis,* has been commonly reported overseas to be an important constituent of these growths, and bacteria tentatively identified as *Sphaerotilis,* were abundant in most of the growths observed.

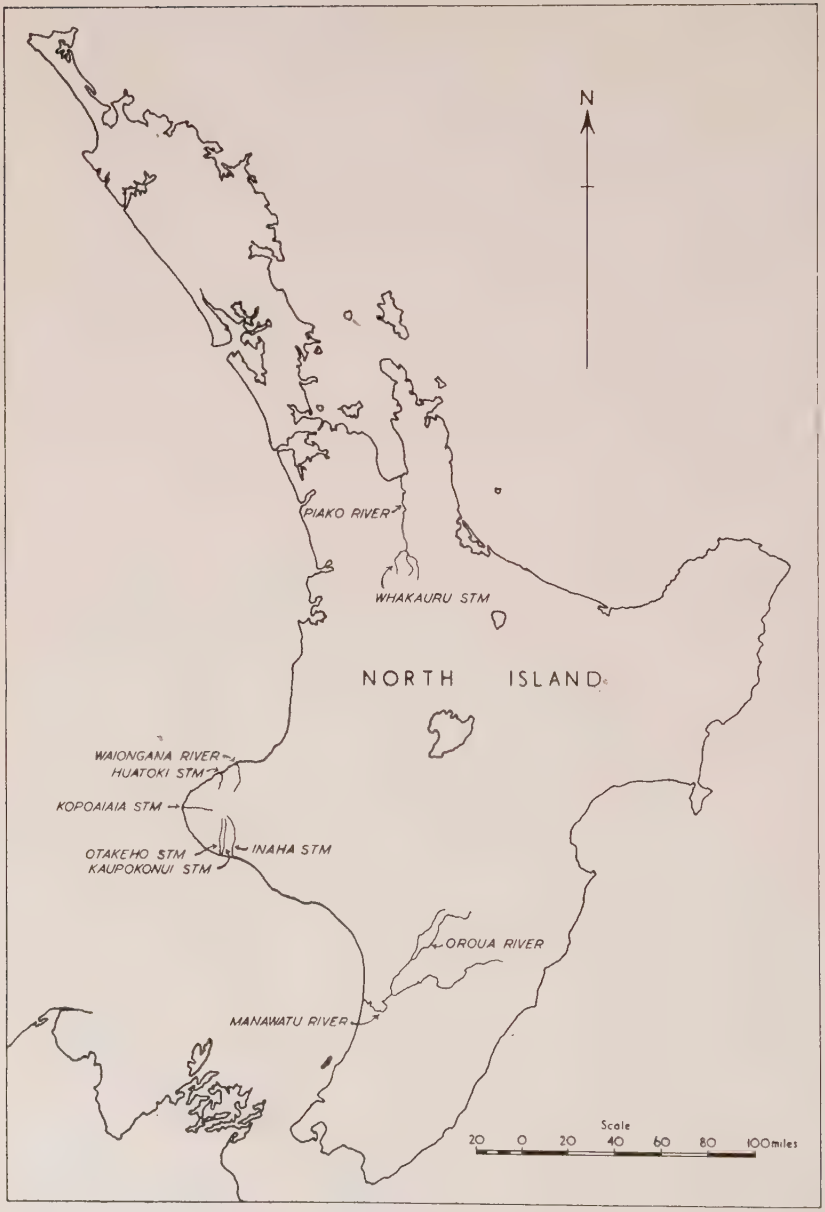

FIG. 1.—Locality map, showing streams sampled in the North Island, New Zealand

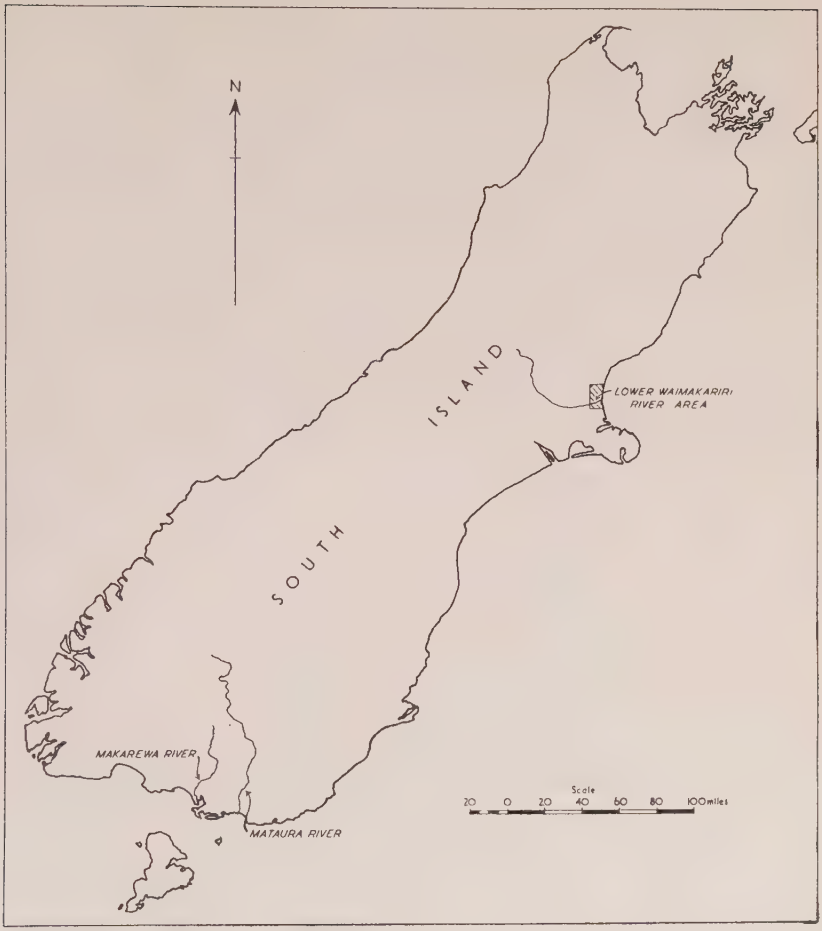

FIG. 2.—Locality map, showing streams sampled in the South Island, New Zealand.

1931) have discussed these factors as they relate to the distribution of the bottom fauna in New Zealand streams. It was not within the scope of this study to explain the reasons for such variations in the samples collected, but rather to determine which effects were caused by, and reflected pollution.

The pattern of changes in the bottom fauna which emerged in sampling various streams, made it apparent that some of the changes were associated with pollution. The significant changes in the bottom fauna observed above and below the entrance of pollution, ranged from great to none at all, presumably dependent on the degree of

pollution. The order of reappearance of organisms in the fauna of recovering streams, or the order of their disappearance in streams where the fauna was only partially affected, gave indications of the relative sensitivities of the various groups. A complete list giving the relative tolerances of the various species encountered could not be compiled, because the sampling was not intensive enough to determine the reactions to pollution of some of the organisms which were of sparse or sporadic occurrence. In addition, taxonomic difficulties prevented the separation into species of many of the organisms, and these must be discussed as families or groups.

Those organisms or groups of organisms for which the reactions to pollution could be determined are discussed in Appendix I, together with other pertinent observations. The following discussion is limited to the more important aspect, that of the effects of pollution on the general assemblages of fauna. Several investigators have stressed that the general composition of the fauna is more indicative of the degree of pollution than is a list of the species present. Gaufin and Tarzwell (1956) have pointed out that, although a number of workers have attempted to associate lists of species with different degrees of pollution, there has been considerable lack of agreement in their findings. They found, in a study of a small polluted stream, that all species of invertebrates found in polluted zones were also found in smaller numbers in clean water zones and concluded that few definite statements concerning the degree of pollution could be made based on the mere presence of certain species. Despite this, fairly definite conclusions could be formulated, based on the assemblages of organisms present. This was found to be the case in the present study, also. The individual species or groups of organisms discussed in Appendix I combined to form faunal assemblages that were indicative of the degree of pollution. The most abrupt change in the assemblages of fauna observed was in the Oroua River (Table 8) where the fauna was almost completely absent at some of the polluted stations. A more characteristic change associated with severe pollution was the restriction of the fauna to one composed principally of tubificid worms and sometimes including the *Chironomus zealandicus* group, other chironomids, and naid worms. Further downstream with recovery, or initially, if the degree of pollution was less severe, a molluscan fauna was often abundant as well. With still further recovery, or a lesser degree of pollution, the various caddis flies and other recovery organisms* returned, sometimes accompanied by a

*Organisms that are able to withstand conditions occurring in areas recovering from septic pollution, or polluted, but not to the septic point, are termed recovery organisms for the purpose of convenience in this discussion, although the various organisms in the group exhibited considerable variation in the degree of pollution that they could tolerate.

decrease in the tubificids. Finally, with further recovery, the sensitive mayfly group returned to the fauna or, with mild pollution, this group was unaffected.

Samples collected from the Kaupokonui Stream (Table 10) in March, 1957, clearly illustrate these typical effects (see Figs 3 to 6). Fig. 3 shows a normal clean-water fauna, collected above all sources of pollution. Mayflies are abundant, with several genera present. Fig. 4 shows the fauna below the discharge from a lactose-powder factory which was causing serious pollution; there the fauna is restricted to tubificid and naid worms and the *Chironomus zealandicus* group. In the recovery zone farther downstream, Fig. 5, there is an abundant molluscan fauna, with recovery organisms such as *Curtisia, Hydora,* and a few caddis flies present as well. Still farther downstream, Fig. 6, the fauna shows almost complete recovery, with mayflies again present, although not abundant. The relative proportion of mayflies to tubificids in the bottom fauna is a good general guide for field observations. If the mayflies are abundant and the tubificids scarce, no pollution damage is indicated. If, on the other hand, mayflies are scarce or absent, and the tubificids abundant, pollution damage is indicated and a more detailed analysis of the fauna will reveal to what degree.

Environmental Limitations

The presence of assemblages of organisms similar to those discussed above, was dependent on suitable environmental conditions being present, apart from the effects of pollution. These assemblages were described in general terms which allow for the evaluation of pollution without regard to minor natural variations in the fauna and were found to be usually satisfactory for stony-bottomed streams. This was not always the case, however. The fauna of the Waimakariri River (Table 1) above and below the entrance of the South Branch was so sparse and subject to changing conditions because of the shifting, unstable nature of the bed, that it was of little use in evaluating pollutional conditions.

Biological assessment of pollution was feasible to the greatest degree in streams with a fauna well represented, both by types and numbers of organisms. A comparison of data from the North Branch, Waimakariri River (Table 2) and the Makarewa River (Table 6) illustrates this point. The fauna of the North Branch, Waimakariri River, was varied above pollution (Stations 1 and 2). At Station 3, below the point of discharge, the fauna was markedly restricted by pollution. At Station 4, although the fauna was still indicative of pollution damage, the sericostomatid caddis flies were again well represented, indicating some degree of improvement in conditions over Station 3. In the Makarewa Rivere, the fauna was less varied above

FIG. 3.—Assemblage of bottom fauna indicative of clean-water conditions. Station 1, Kaupokonui Stream, March 1957.

FIG. 4.—Assemblage of bottom fauna indicative of gross pollution. Station 7, Kaupokonui Stream, March 1957.

FIG. 5.—Assemblage of bottom fauna indicative of partial recovery. Station 10, Kaupokonui Stream, March 1957.

FIG. 6.—Assemblage of bottom fauna indicative of almost complete recovery. Station 14, Kaupokonui Stream, March 1957.

pollution (Station 1) with caddis flies scarce. Thus, although the fauna at the polluted stations (2 and 3) was generally similar to the fauna at Station 3 of the North Branch, it was not clear whether the same degree of pollution damage had occurred or whether the pollution was of a somewhat lesser degree, as for example, at Station 4 of the North Branch.

Sand and silt-bottomed streams offered little suitable substrate for the development of some of the groups found to be most useful for pollution evaluation in stony-bottomed streams. A paucity of fauna was encountered in the sandy-bottomed areas of the Piako River and its tributary, the Waitakaruru Stream (Table 13), for example. Growths of aquatic weeds in such areas afforded a substrate for the development of a richer fauna, as could be seen at Station 1, Piako River, where the faunas collected from the weeds and from the predominantly sandy bottom were tabulated separately. Some other sandy-bottomed streams (e.g., Inaha Stream, Table 2, Whakauru and Matarawa streams, Table 12) afforded faunas more useful for pollution evaluation, but these faunas were still not as varied as those of many stony-bottomed streams. In addition, some of these soft-bottomed areas supported populations of organisms which were indicative of pollution when found in stony-bottomed areas, possibly because of the amount of organic matter present in the bottom. The small tributary of the South Branch, Waimakariri River (Table 1), was an example of this. The bottom in the unpolluted area (Station 9) consisted of sand covered with a deposit of coarse organic debris. The fauna here would have been clearly indicative of pollution had it been found in a stony-bottomed stream. A less extreme difference between the faunas of two unpolluted stations could be seen in the North Branch, Waimakariri River. There, Station 1 had a predominantly shingle bottom, while Station 2 was a pool area with a bottom composed of sand and organic debris, but with some shingle present as well. The proportion of pollution-tolerant organisms was greater at this point than it was at Station 1.

More detailed investigation of the fauna of sluggish mud-bottomed streams than was made in this study might reveal characteristic fauna of clean mud bottoms. Butcher (1928), for example, found that a number of species found in clean mud bottoms, did not occur in heavily polluted muds. Wright (1955) suggested a biological index of pollution for mud bottoms in Lake Erie. A mud bottom having fewer than 100 tubificid worms and more than 100 nymphs of the burrowing mayfly, *Hexagenia*, was considered free from pollution. Wright further recognized three degrees of pollution based on the numbers of tubificids per square meter; light pollution, 100 to 199; moderate pollution, 1,000 to 5,000; heavy pollution, over 5,000. There is no similar widespread and abundant burrowing mayfly fauna which could be used for pollution evaluation in soft-bottomed New Zealand streams. The increase of tubificids in soft bottoms with pollution was apparent

in some cases. For example, in the Piako River there was a great increase in tubificids from the unpolluted to polluted sandy bottoms. A subsequent very apparent decrease in the numbers of tubificids at Station 5 as compared with their numbers at Station 3 occurred too, although the method of recording the data does not reveal this. However, this method of classification would not in itself be satisfactory as in cases of particularly bad pollution even the tubificids were scarce (e.g., Oroua River, Stations 3, 4, 5, and 6; South Branch, Waimakariri River, Station 7).

Organic matter entering streams from sources such as natural or agricultural drainage undergoes bacterial decomposition, just as does sewage or organic trade waste, although this decomposition may proceed at a much slower rate. If the degree of this natural organic pollution is great, oxygen depletion can occur. The observations made in this study suggested that, in general, these organic materials of both natural and agricultural origin were of small enough quantities for the streams to deal with them without adverse effects. The small headwater of Dunn's Creek (Table 10) for example, contained large amounts of natural organic debris (i.e., leaves, twigs, etc.) yet supported a good mayfly fauna. The report of the Inter-Department Committee on Pollution (1952) estimated cowyard wastes as the greatest source of organic pollution in New Zealand, with a population equivalent of 4,900,000.* But these wastes were discharged in relatively small quantities from many sources. Most of the streams examined in this study flowed through areas receiving agricultural drainage and in some cases were known to receive barnyard wastes a short distance upstream from the areas sampled. Despite this organic enrichment, all these streams supported clean-water fauna if the substrate was suitable, thus indicating that no serious oxygen depletion had occurred. Allen (1951) in the case of the Horokiwi Stream, found no evidence of pollution damage below the point where a cowyard and milking shed regularly discharged wastes, although there was some increase in chironomid larvae. Oxygen depletion, whether caused by natural or agricultural drainage would, of course, be most likely to occur in sluggish streams where organic matter could accumulate on the bottom, and some such streams exhibit signs of pollution prior to the discharge of sewage or trade wastes.

Based on the observations made in this study, pollution evaluation, using the criteria discussed in the section on fauna, should be satisfactory in stable, stony-bottomed streams. In streams with sandy or

*Population equivalent is a term giving the measurement of the oxygen requirements of wastes in terms of domestic sewage from so many people. It is a method whereby the magnitude of pollution from domestic, agricultural, and industrial sources can be compared on the basis of the oxygen demand of the wastes.

silty bottoms, evaluation is more questionable and sometimes may not be possible at all. Examination of stations upstream from pollution in questionable habitats, will reveal in each case whether a fauna is present which will enable pollution evaluation on the basis of these criteria. In some such cases it may be feasible to sample aquatic weeds which afford a substrate for a more varied fauna, but there are no data available in this study to indicate how reliable such sampling would be as compared with actually sampling the stream bottom. Comparison of markedly dissimilar stations is often unavoidable, as in the case of the South Branch, Waimakariri River, where the character of the stream changed below the point of waste discharge. However, such comparisons should be made with an awareness of the differences in the fauna which can occur due to the environmental differences discussed above.

Seasonal Variations

Two general types of seasonal variations were observed:

(1) Natural seasonal variations due to the life histories of the organisms. The marked decrease of *Helicopsyche* and the *Pycnocentrodes* group in the summer samples from the North Branch, Waimakariri River and its tributaries, was one example of this. Large numbers of empty cases were found, indicating that emergence had occurred. Seasonal effects of this nature should not significantly affect the evaluation of pollution based on the criteria discussed above, since the general composition of the fauna would still remain indicative of clean-water or polluted conditions.

(2) Seasonal changes in the degree of pollution. These can be of two types:

(a) Variations in stream conditions such as temperature and flow. The lower winter temperatures decrease the rate of decomposition of the wastes, and thus the oxygen demand is less abrupt and is exerted more gradually over a longer distance of the stream. The generally higher winter flows afford greater dilution, and thus the effect of the wastes on the oxygen resources of the stream is much less.

(b) Variations in the amounts of wastes discharged. In industries with marked seasonal peaks, such as dairy factories and meat-freezing works, these fluctuations are great, with the amounts of wastes discharged during the winter months low.

A combination of effects (a) and (b) exerts a considerable influence on the stream biota and therefore on the evaluation of pollution. The relative importance of these two types of changes varies with the individual case. Where critical stream

conditions coincide with maximum waste discharges, as is often the case with meat freezing works pollution, the effects will naturally be the most serious. In the dairy industry, such peaks may not coincide as closely, as the peak of the dairy season is usually prior to the period of most critical stream conditions. In the two streams where this was observed, the Huatoki Stream (Table 9), and the Kaupokonui Stream, the effect of pollution on the fauna was greater during March, the period of critical stream conditions but somewhat reduced production, than it was in October and November, the period of peak production.

The important question from the standpoint of pollution evaluation is whether biological sampling done during the winter, spring, or early summer months reflects the damage of the previous critical period. Improvement of conditions during the winter allows the survival of organisms in areas which they could not inhabit during the summer. This invasion of unpolluted areas during non-critical periods by small numbers of sensitive organisms was observed in some of the streams where sampling was done at different seasons. The amount of invasion of these polluted areas was probably dependent to some degree on the drifting propensities of the various organisms and the closeness of unpolluted areas upstream to supply these organisms. In the Northbrook Drain, for example, these organisms were more common at Station 3, below the entrance of a small unpolluted tributary than they were at Station 2, just above the entrance of the tributary. In the Huatoki Stream and the Kaupokonui Stream, the mayflies showed greater repopulation of some polluted areas than did less sensitive organisms such as sericostomatid caddis flies, suggesting that they drift more readily.

The growth of sewage fungus in polluted streams are reported to often extend farther downstream in the winter than in the summer (Southgate, 1948). This is due to the slower rate of decomposition, which make organic nutrients available to the growths over a greater distance of stream. This cold weather extension of sewage fungus growths was observed in the Kaupokonui Stream and the North Branch, Waimakariri River, but in the Manawatu River (Table 7) and the Oroua River, the growths were much greater during the late summer than earlier in the season, probably due to the greater amounts of wastes discharged at that time. In an intensive study of a small polluted stream, Gaufin and Tarzwell (1955) found that the downstream extension of this sewage fungus blanket in winter destroyed clean-water organisms downstream from the areas of summer pollution damage. Thus, biological pollution damage extended farther downstream in the winter than during the summer, even though the chemical and physical conditions were less critical. This effect was not observed in the course of the present study.

The data show that pollution evaluation can be conducted during non-critical periods but that the results are sometimes less clear-cut and more subject to judgment in interpretation. Polluted zones were usually apparent from the general composition of the fauna, but clean-water organisms were present in small numbers in some cases. In the case of the Oroua River, where the fauna was virtually destroyed at some stations during the summer period, the only indication of past pollution damage was the obvious paucity of organisms at these stations.

Correlation of Bottom Fauna With Degree of Pollution

Close correlation of the biological conditions observed in polluted areas with definite chemical and physical values would be desirable. Chemical and physical values, such as dissolved oxygen or suspended solids concentrations are recognized as the standard criteria of pollution and are used in measuring pollution, in setting legal limitations on the degree of permissible pollution, and in designing waste treatment. Thus, although the biological consequences of pollution can be measured by the method described above, ability to define the degree of chemical and physical pollution that has occurred, based on the observed effect on the biota, would be extremely useful for application to pollution problems.

The correlation of the biological changes with the physical and chemical conditions which caused them would require intensive sampling during the period when the maximum deleterious effects were present, that is, the period of critical pollutional conditions. Such critical data are often difficult to obtain for the reasons discussed in the introduction. In addition, there are a number of variable pollutional effects involved in bringing about changes in the bottom fauna:

Oxygen Depletion

The dissolved oxygen concentration is well recognized as an important factor determining the distribution of aquatic organisms in polluted streams. Dissolved oxygen data were collected in conjunction with much of the biological sampling done in this study, but it would be fortuitous should such data represent the true minima. Even when the data were collected during critical periods, the diurnal variability in waste discharge and the diurnal effects on the oxygen concentrations of photosynthesis and respiration by algae and aquatic weeds made it unlikely that the minima would be detected. Although the dissolved oxygen data, therefore, may not represent the worst conditions to which the organisms in a given area were subjected, they did show that certain organisms could survive at oxygen concentrations at least as low as those recorded. Thus, in the small stream (A) near Auroa (Table 11) it was evident that tubificids and some chironomids (mostly *Chironomus zealandicus* type, with ventral blood-gills) could survive at 0·2 p.p.m. Conversely, in the Northbrook

Drain (Table 3) it could be seen that concentrations of 6·1 p.p.m. had no detectable effect even on the sensitive mayfly group at Station 6. The duration of the oxygen depletion determines to some extent the ability of the organisms to survive. The water temperature affects this as well, since the metabolic requirements of the organisms increase with increasing temperature. Even the most pollution-tolerant inverterbates would probably succumb to septic conditions if these were prolonged enough. Lindeman (1942) for example, found that mixed populations of *Tubifex,* pollution tolerant *Chironomus* larvae, and other macroinvertebrates could survive anaerobic conditions of 120 days, but his results indicated that none of these organisms would be able to survive anaerobiosis indefinitely. Pennak (1953) quotes Dausend, who showed that only a third of the individuals of *Tubifex* were able to survive anaerobic conditions for 48 days at 0° to 2° C, and the percentage of survival was smaller at higher temperatures.

Toxic Substances

Toxic pollution is often associated with industrial processes which discharge inorganic toxic substances to streams. This type of pollution is not widespread in New Zealand, and no cases were investigated in the present study. However, some toxic substances, such as sulphides, ammonia, and carbon dioxide, are frequently associated with organic pollution, occurring either as decomposition products or as components of the wastes discharged, such as sulphides in the case of fellmongeries.

Stammer (1953) investigated experimentally the effects of hydrogen sulphide and ammonia on aquatic organisms of varying pollution tolerance. His results suggested that the pesence of these toxic components of decomposition would have the same adverse effect on organisms as dissolved oxygen depletion. He concluded that dissolved oxygen content would be the decisive factor in slow-flowing or stagnant water, but that toxic substances, especially ammonia, might be the main influence in polluted, but rapidly flowing, and therefore oxygen-rich water. It was clear in the present study that marked oxygen depletion occurred even in rapidly flowing streams (e.g., Huatoki Stream, Kaupokonui Stream, Oroua River). However, toxic components were undoubtedly present as well in at least some cases. For example, in chemical sampling in connection with the February survey of the North Branch, Waimakariri River, the Government Analyst, Christchurch, found an ammoniacal nitrogen concentration of 1·44 p.p.m. at Station 4, which was higher than the concentration found by Stammer to kill organisms usually restricted to clean-water or mildly polluted stretches of streams.

Changes in the Substrate

The deposition of sludge, which sometimes occurs in polluted areas, renders the bottom unsuitable for organisms requiring a firm sub-

strate, as well as exerting an oxygen demand. The abundant growths of algae and sewage fungus, often stimulated by pollution, also cause changes in the environment, both by covering the substrate and by entrapping large quantities of silt. Areas with very heavy algal growths were observed to support normal populations of clean-water fauna in unpolluted areas (e.g., South Branch, Waimakariri River, Station 1; Kaupokonui Stream, Stations 4 and 5). Sewage fungus growths, however, more closely blanket the substrate when extremely abundant and in such cases these may exert an adverse effect. Gaufin and Tarzwell (1955) pointed out that the downstream extension of the sewage fungus blanket in winter destroyed much of the clean-water fauna, sometimes actually forming heavy growths on the organisms themselves. This was during a period when the dissolved oxygen concentrations were believed to be adequate.

A number of interacting adverse factors, then, act to modify the faunae of polluted streams, and this would prevent the assigning of exact physical and chemical values to the amount of pollution that has occurred even if more adequate data were available. Despite this general correlations of the degree of chemical and physical pollution with the biota have been made. Kolkwitz and Marsson (1908, 1909) described a saprobic system, which was later revised by Kolkwitz (1950), in which they defined the zones in polluted streams as "Poly-saprobic zone" grossly polluted; "Meso-saprobic zone", subdivided into "α meso-saprobic", polluted "β meso-saprobic", mildly polluted; and "oligio-saprobic", unpolluted. They discussed in general terms the chemical and physical pollutional conditions occurring in those zones, and listed the various aquatic organisms characteristic of them. Hawkes (1957) gave a revised general outline of Kolkwitz and Marson's saprobic system. A number of workers have followed the general procedure of describing conditions in the different sections of polluted streams, sometimes referring to them as zone of degradation, zone of active decomposition or septic zone, zone of recovery and clean-water zone, and describing the faunas characteristic of them.

The data available or collected in the field during the course of this study were inadequate to illustrate these zones or degrees of pollution in chemical and physical terms. The general degradation and self-purification processes occurring in the polluted streams examined, however, can be assumed to be the same as those described in the literature. Despite the lack of detailed chemical and physical data, a number of inferences can be drawn based on the observations made, and put to practical use in the assessment of pollution.

Bottom faunas consisting principally of tubificids or tubificids and the *Chironomus zealandicus* group, some other chironomids and naid worms, are indicative of severe pollution and probably septic or near septic conditions. In particularly bad cases the fauna may have almost entirely disappeared with even these tolerant organisms becoming

scarce. The sequences of faunal assemblages occurring downstream, as described in the section on the effects on the fauna, can be associated with lesser degrees of pollution or increased recovery, but these intermediate degrees of pollution cannot be clearly delineated with the data available.

It was apparent that the mildest cases of pollution which could be detected by biological sampling were those in which the wastes were strong enough to cause organic enrichment but not strong enough to cause serious oxygen depletion or adverse toxic effects. These were the cases where pollution tolerant organisms increased, but there was no decrease in the sensitive species (e.g., South Branch, Waimakariri River, Station 3). Still milder cases of this sort were those in which the growth of sewage fungus was stimulated but there was no detectable effect on the bottom fauna (e.g., Manawatu River, Station 3, Table 7). In some cases of mild pollution, the only detectable biological change may have been the stimulation of algal growths. This is difficult to detect quantitatively by field observation, unless the increase is very marked, and in such cases, the effect would probably be detectable by changes in the bottom fauna as well. However, qualitative examination of the algal samples collected in the course of the study may show that mild pollution effects can be detected by changes in the composition of the algal flora.

The orders of size used are applicable to the one stream, i.e., "large" means large for that particular stream. This scale may well be modified or superseded when more rivers have been examined in detail.

Fisheries Damage

In the two streams where attempts were made to correlate the effects on the bottom fauna with damage to the trout fisheries, differing results were obtained. In the North Branch, Waimakariri River, trout populations were virtually absent from the polluted area during both winter and summer sampling periods. In the Northbrook Drain, which was sampled in early summer, a heavy trout population was found in an area (Station 3) showing at least as much damage to the bottom fauna as that recorded in the North Branch.

It is apparent that a certain degree of pollution damage to the bottom fauna would be accompanied by damage to the fish population. However, the mobility of fish makes them less reliable for reflecting past conditions than are the bottom fauna. They could be killed in or absent from a given polluted area and then repopulate it during the period when conditions improved, particularly when they have ready access from nearby unpolluted areas. Thus, their presence could be merely indicative of present conditions rather than reflecting past conditions. Unfortunately, the Northbrook Drain could not be examined during the critical late summer period to determine whether trout were present then. The virtual absence of trout at

Station 3 of the North Branch during the winter period may have indicated that conditions were unsatisfactory for their survival even during that period. The fellmongery wastes entering the stream could have contained toxic chemical components which would have rendered the downstream area unsuitable even if the dissolved oxygen was high during the winter period.

The data collected from the North Branch indicated that brown trout are more sensitive to pollution effects than are bullies or adult whitebait. Eels are apparently attracted to polluted areas, being observed in marked abundance in a number of polluted streams.

Application of the Biological Method

The value of the biological method outline above in pollution investigation work is that it enables the assessment rapidly and in general terms of the degree of pollution damage to a stream and whether or not a given waste markedly exceeds the self-purification capacity.

For example, in the case of the Kaupokonui Stream, a municipal septic tank serving a population of about 500, and two cheese factories discharged upstream from the lactose powder factory. The population equivalent of the wastes from the cheese factories is not known, but since they discharged only wash-water, disposing of their whey elsewhere, it is not believed to be great. The population equivalent of the wastes discharged from the lactose powder factory during peak production periods was estimated at about 5,000. From the biological survey it was apparent that the wastes from the lactose powder factory exerted a demand exceeding the self-purification capacity of the stream over a distance of some miles, while the other sources had little effect*. Similarly, on Dunn's Creek, the cheese factory discharging wash-water wastes to the headwater area where the flow was very small, created a septic zone, while a similar factory discharging farther downstream where the flow was much greater had no detectable adverse effect.

An unpublished report to the Pollution Advisory Council by the Ministry of Works (1957) entitled "Pollution in the Lower Manawatu and Oroua Rivers" shows that wastes with a population equivalent of 183,000 were discharged to the Oroua River at Feilding. This caused almost complete depopulation of the fauna just downstream.

*It must be stressed, however, that negative results obtained by biological sampling are not adequate where the bacterial quality of the water is a consideration. The lactose-powder factory exceeded the purification capacity and created nuisance conditions, while the municipal septic tank did not. However, apart from these nuisance conditions, the discharge of pathogenic organisms and therefore the danger to health, would be likely to be greater in the latter case. Thus, in cases where the bacterial purity of the water must be determined, this should be done by a programme of bacterial sampling coupled with a sanitary survey.

Combined with additional wastes with an estimated population equivalent of 13,000 entering farther downstream near Bonness Road, this was enough to virtually destroy the fauna over some miles of river. The estimated low flow for the river in this stretch was 65 cusecs. In the nearby Manawatu River the estimated low flow was 400 cusecs. There, wastes with an estimated population equivalent of about 35,000 were discharged from the municipal septic tank, which was the major source of pollution above Station 5. There was no detectable effect on the bottom fauna, although the growth of sewage fungus was stimulated. Farther downstream, wastes with an estimated population equivalent of about 150,000 were discharged. Below this point (Station 6) the fauna was partially affected, with the sensitive mayfly group disappearing. The fauna recovered a short distance downstream (Station 7), although growths of sewage fungus remained common over the stretch sampled. It was apparent, then, that while the self-purification capacity of the Oroua River was markedly exceeded, wastes of similar polluting strength did not cause serious oxygen depletion or adverse toxic effects on the stretch of the Manawatu River sampled because of the greater dilution afforded.

Again, in the case of the Mataura River (Table 5), it could be seen that the wastes entering the river at Gore and Wyndham had little effect, while the greater magnitude of wastes discharged at Mataura caused partial pollution damage.

These examaples illustrate the type of information which can be obtained by biological sampling. In some of these cases, the pollution was obvious visually or through the dissolved oxygen analyses, but the extent was not clear. For example, when the Kaupokonui River was examined in March, 1957, pollution from the lactose-powder factory was apparent both visually and in the chemical sampling as far downstream as Station 8. The pollution was not apparent at Stations 9 or 10, but the biological sampling showed that damage had extended at least this far. Chemical measurement of the extent of pollutioni n this case would have required intensive sampling and this would have been accurate only if done under the most critical conditions, which might have already passed. In general, the pollution investigator cannot depend on casual chemical sampling to give a reliable picture of the true extent of pollution. While the biological results cannot be expressed precisely as can the chemical data, the investigator can determine the magnitude of the problem in a fairly rapid field survey. Often this information is adequate for application in pollution abatement activities.

The biological method can in some cases be applied by personnel with limited biological background. Stony-bottomed streams sampled

during or shortly after the critical period often show the effects of pollution very clearly. In other cases, limitations in the nature of the sampling stations and seasonal changes necessitate more judgment in the collection of samples and the interpretation of results. For this reason, biological investigations of pollution can be most successfully carried out by personnel with an understanding of the natural factors influencing the distribution of aquatic organisms in streams.

APPENDIX I

Bottom Fauna

Ephemeroptera

The *Deleatidium* group consisted of the genera *Deleatidium* and *Atalophlebia*. Preliminary examination of a number of samples indicated that the reaction of both genera to pollution was the same and so they were grouped together for convenience in counting. Other mayflies commonly encountered were *Nesameletus* and the swift-water form, *Coloboriscus humeralis*, but these were of more scattered distribution in the samples. The mayflies as a group were particularly sensitive to pollution. They were found to be the first common group to disappear under polluted conditions and the last to reappear in streams recovering from pollution. Mayflies could be expected to be common in areas of stony, stable bottom, and the absence of the group in such areas was an indication of pollution. Allen (1951) reported the *Deleatidium* group to be unusually uniform in the Horokiwi Stream, both in distribution in the stream and seasonally. It was also found to be widespread in suitable habitats in this study, and thus this group was a particularly useful indicator of stream conditions.

Trichoptera

The various groups or species of caddis flies were not as widely and uniformly represented in the streams sampled as were the mayflies, particularly the *Deleatidium* group. However, some of these were extremely abundant in a number of streams and they were found to be useful indicators of pollutional conditions. The taxonomic status of many of the New Zealand larvae is not clear, and most of them are discussed below as groups or families.

Sericostomatidae

The *Olinga* group included the one described species, *Olinga feredayi* and larvae of similar appearance but having sand grains arranged in regular rings over the the horny material of the case. The *Pycnocentrodes* group contained larvae of this genus and others of generally similar appearance, probably including *Pyncnocentria*. Both these groups were abundant in a number of the streams sampled and were

tolerant of a considerable degree of pollution, although they were not found in the most seriously polluted areas. The position was not clear for *Helicopsyche,* but in the North Branch, Waimakariri River, it appeared to be somewhat more sensitive than the other Sericostomatidae. *Beraeoptera* was found in high numbers in the Kaupokonui Stream, but it was restricted to samples from the upper reaches above the entrance of serious pollution and no assessment could be made of its sensitivity.

RHYACOPHILIDAE

The various species were usually found in relatively small numbers and determination of the sensitivity of all the species could not be made. At least two species, however, were found to be tolerant of severe pollution conditions. *Hydrobiosis parumbripennis* and *H. umbripennis* were common in areas where the fauna was seriously restricted in the Kaupokonui Stream and the Northbrook Drain. These were the most pollution tolerant of the caddis flies for which sensitivities could be determined.

Hydropsychidae: These larvae were not separated taxonomically, but many or all of them were probably *Hydropsyche,* which is the common genus in New Zealand. Although this group was an important one, frequently being very abundant, the larvae were of relatively sporadic occurrence in the samples, even when they were collected from apparently similar habitats in the same stream. Thus, when Hydropsychidae were absent from a sample below a point of waste discharge it was not always clear whether this was due to pollution. This group was a recovery one, but relatively sensitive compared to the tolerant Sericostomatidae and recovery organisms of other groups.

OTHER TRICHOPTERA

The other families of Trichoptera were of less importance. The Leptoceridae larvae were tentatively identified from illustrations in Hudson (1904) as *Hudsonema amabilis* and *Triplectides obsoleta. Hudsonema* was a recovery organism and appeared to be similar in tolerance to the tolerant Sericostomatidae. The Polycentropodidae were only encountered in clean-water areas, but as they were seldom found, and then only in small numbers, their sensitivity was not clear.

Several genera of Hydroptilidae are listed from New Zealand (Mosely and Kimmins, 1953) and the taxonomic status of the larvae collected was not determined. Hydroptilidae larvae resembling those illustrated in Hudson (1904) as *Oxyethira albiceps* and *Oxyethira* sp. were found in the recovery zones of several streams.

Coleoptera

The only bettle commonly encountered was the parnid, *Hydora,* almost always collected in the larval stage. The larva was a recovery organism apparently tolerant of much the same degree of pollution as the pollution-tolerant Sericostomatidae.

Diptera

CHIRONOMIDAE

This important family was often very abundant in the streams sampled. Most of the larvae could not be identified and thus a number of specific relationships to pollution may have been masked. Paine and Gaufin (1956), for example, showed that the various species of chironomidae in a small stream exhibited a wide range of tolerance to pollutional conditions.

The *Chironomus zealandicus* group consisted of the larvae commonly known as "bloodworms" and easily recognized by their large size and bright red colour. Two types of larvae could be recognized in this group, those with four ventral bloodgills on the penultimate segment and larvae of similar appearance and mouth-parts (with a trilobed labial plate) but lacking ventral bloodgills. Some of these larvae were probably the type known as *Chironomus zealandicus*. Hudson (1892) described the *Chironomus zealandicus* larva as being extremely abundant throughout New Zealand, inhabiting the soft mud at the bottom of stagnant streams and ponds. However, as the taxonomic status of this larva is uncertain, Hudson may have actually been referring to more than one species. In this study, the *Chironomus zealandicus* group was common in some unpolluted soft-bottomed habitats (e.g., Station 2, North Branch, Waimakariri River). However, its abundance in stony-bottomed areas was an indication of pollution. The group was common in badly polluted areas of many streams, being able to withstand septic conditions. Although the samples were not usually separated into gilled and gill-less larvae in analysis, there was some indication that these two types may have exhibited different tolerances to pollution. For example, in the small drain carrying soap-wastes to the South Branch, Waimakariri River, almost all the larvae collected from the soft organic bottom above the outfall were gill-less while almost all those collected from the polluted sludge bottom below the outfall had gills.

Some other chironomids, small green forms in most cases, were also able to withstand serious pollution, being found abundantly in areas showing marked restriction of the fauna, sometimes in association with the *Chironomus zealandicus* group. A number of the small green chironomids abundant at Station 4 in the polluted stretch of the North Branch, Waimakariri River, were reared in the laboratory and found to be *Chironomus pavidus*. In the Kaupokonui Stream the *Chironomus zealandicus* group was abundant in the badly polluted stretch in March, but small green chironomids were abundant there at other times when conditions were less critical.

OTHER DIPTERA

The other families of diptera encountered were of sparse or sporadic occurrence, and thus were of relatively little value in reflecting pollutional conditions.

Other Insecta

The Neuroptera larva, *Archichauliodes dubitatus,* was often encountered in small numbers. Based largely on its distribution in the Kaupokonui Stream, where it was found at many stations, it was a recovery organism. Plecoptera larvae were infrequently encountered and they were particularly scarce in summer samples. Although stoneflies were too sparse to draw definite conclusions, overseas workers have regarded this group as a particularly sensitive one (as they have the mayflies) and it appears likely that the New Zealand stoneflies are in the same category. Zygoptera and Lepidoptera larvae were found commonly only in heavily weeded areas in a few streams. They were absent under conditions of gross pollution, but their relative sensitivity under conditions of milder pollution could not be determined.

Crustacea

The only crustacean frequently encountered was the small amphipod, *Paracalliope fluviatilis.* As Percival (1932) and Phillips (1929) have pointed out, it showed a marked preference for areas where the aquatic vegetation was abundant, but it was sometimes common elsewhere, particularly where the current was not extremely rapid. It appeared to be typically a recovery organism. However, it was often abundant under the overhanging grassy banks of small streams, and there it could survive when conditions were probably too severe for it in the open stream bed. For example, in the small stream (A) near Auroa it was absent in the open stream bed, but common under the overhanging grassy banks in the polluted area. At the unpolluted station upstream it was very abundant in the open stream bed. In the Northbrook Drain, Station 2, which was similar in character, it again appeared to be confined to the marginal areas near the overhanging grassy banks. In such places, then, it can survive in marginal areas not subjected to conditions which occur in the open stream. Because of its relative mobility it could move from such areas into the open stream bed when conditions were not critical.

Mollusca

Potamopyrgus was the most commonly encountered mollusc. Several species were found: *P. antipodum, P. badia, P. corolla* (and *P. corolla salleana*). The separate species were listed in the tables of data, wherever idenifications were obtained. However, in each case, only a portion of the total collection was retained for identification, and it is possible that other species were present as well. *Potamopyrgus* was found to be very abundant on aquatic weeds, and also on the stream bottom itself, particularly where the current was not extremely rapid. All the species encountered were able to tolerate a marked degree of pollution, more so than the recovery organisms discussed above, but not septic conditions.

Physastra variabilis and *Planorbis corinna* were both tolerant of a marked degree of pollution. Both species are apparently principally quiet water forms. They were both common in the "Groynes" pool of the South Branch, Waimakariri River. *Physastra* was common in the pool area (Station 2) of the North Branch, Waimakariri River, as well. The abundance of either species in stony-bottomed areas with flowing current was an indication of pollution.

Pisidium novaezelandiae was found to tolerate recovery conditions or to be stimulated by mild pollution in several streams. *Gundlachia lucasi* was found in the area of the Makarewa River showing partial pollution damage, while the North Island species, *Gundlachia neozelanica,* was found in markedly polluted areas of the Kaupokonui Stream, showing the same degree of tolerance as the other molluscs discussed above.

Annelida

TUBIFICIDAE

Tubificid worms were found under conditions ranging from clean water to septic pollution, but as the species concerned were not identified it was not clear whether the same species were present under the various conditions. Tubificids were the most ubiquitous of the pollution-tolerant organisms, being found in almost all polluted areas where changes in the bottom fauna were observed, often in extreme abundance. They were sometimes abundant in unpolluted areas with sand or silt bottom, and in some cases they were found to be fairly common in unpolluted areas with stony bottoms. However, in such cases it was observed that they were present in the sand underlying the surface shingle, and thus the depth to which the bottom materials were disturbed in sampling determined whether or not tubificids would be collected. In polluted shingle bottoms, tubificids were frequently extremely abundant and these were observed to be closeley associated with the stony substrate itself. In some such cases clusters of worms were found on the underside of the surface stones. The abundance of tubificids on actual stony substrates was an indication of pollution.

NAIDIDAE

Because of their small size and the difficulty of detecting them in samples containing much debris or algal material, the distribution of naid worms in some of the streams sampled was not clear. They were, however, found under the same wide range of pollutional conditions as the tubificids, and they presented the same taxonomic difficulties as did that group. They did not frequently comprise the bulk of the bottom fauna in polluted areas as did the tubificids, and were generally less useful for pollution evaluation.

TURBELLARIA

The two commonly encountered species of planarians, *Curtisia stagnalis* and *Spathula fontinalis*, were found to be recovery organisms. *Dugesia montana* was less frequently found. In the Mataura River it was present at a number of stations, but absent at Station 5 where pollution damage occurred. In the Makarewa River, *Dugesia montana* was found above pollution and *Curtisia stagnalis* at the two polluted stations.

An undetermined species of Rhabdocoel was common at two stations in the badly polluted stretch of the South Branch, Waimakariri River.

APPENDIX II

STREAM SAMPLING

The details of the stream sampling and the results obtained are presented below. Bottom fauna are listed in the tables of data as numbers per square foot, or in the case of quantitative data, bottom fauna, algae, and sewage fungus are listed in the categories described in the section on methods:

BOTTOM FAUNA		ALGAE AND SEWAGE FUNGUS
—: none found	—: none found	—: none found
S: scarce	a: 1	S: scarce
C: common	b: 2 to 3	C: common
A: abundant	c: 4 to 6	A: abundant
V: very abaundant	d: 7 to 12	B: blanketing bottom
	e: 13 to 24	V: very abundant
	f: 25 to 49	
	g: 50 to 99	
	h: 100 to 199	
	i: 200 to 399	
	j: 400 and over	

Bottom materials are listed as bedrock (Be), boulder (Bo), detritus (leaves, twigs, coarse organic matter, etc.) (D), sand (Sa), shingle (Sh), silt (Si), sludge (fine organic sludge associated with pollution) (Sl), and weeds (W). Estimated widths, or flow data where these were available, are given merely to indicate the approximate size of the stream. Flow data were obtained from the Hydrology Annuals (Soil Conservation and Rivers Control Council) 1953, 1955, 1957, or in some cases from local sources.

Table 1.—South Branch, Waimakariri River.

SOURCES OF POLLUTION AND SAMPLING STATIONS. Wastes from two meat freezing works, a wool scour, and a soap factory. Locations are shown in Fig. 7.

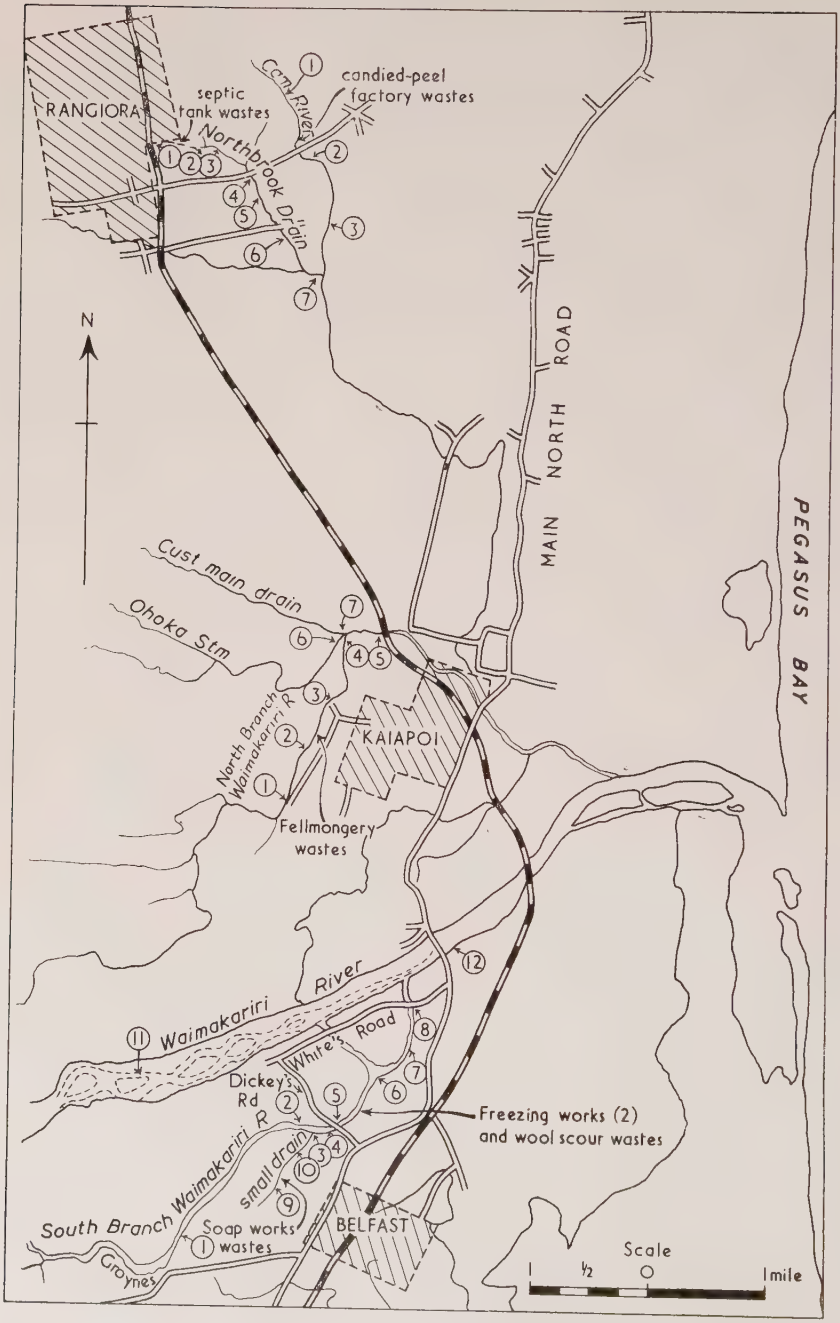

FIG. 7.—Map of lower Waimakariri River area, showing numbered sampling points in relation to sources of pollution.

DESCRIPTION. The stream is stable, arising from seepage under the stopbank of the Waimakariri River. Average flows in the stretch sampled were probably over 100 cusecs. From the "Groynes" pool downstream to below Dickey's Road Bridge the stream is rapid, flowing over predominantly shingle bottom with abundant growths of aquatic weeds in many areas. Below Dickey's Road Bridge the stream flows through the old bed of the Waimakariri River, becoming broad and sluggish. The bottom here is sand and shingle covered with deposits of waste materials ranging from coarse debris, such as hair and paunch contents, to fine organic sludge farther downstream. Aquatic weeds were absent in this area.

The tributary entering the stream above Dickey's Road Bridge is a small drain with an estimated flow of under 1 cusec. The sand bottom is covered with coarse organic debris above the point of discharge of soap factory wastes, and with deposits of fine organic sludge below this point.

The Waimakariri River is large, with flows of over 1,000 cusecs, and with unstable, braided, shingle bed, where sampled above and below the entrance of the South Branch.

SAMPLING PERIODS. June 1956, March 1957. The latter period was during the peak killing season at the freezing works. Dissolved oxygen data were supplied by the Government Analyst, Christchurch. Chemical sampling was conducted prior to biological sampling during the summer period, and the dissolved oxygen data for this period were collected in February.

COMMENTS. The change in habitat due to the broadening of the stream bed below Dickey's Road Bridge could be expected to affect the fauna apart from the effects of pollution. The "Groynes" pool was the only area upstream showing similar conditions of slow current. Quantitative samples could not be collected here because of the depth and hardness of the bottom. However, cursory observations revealed an abundant molluscan fauna, composed largely of *Potamopyrgus*, but with *Physastra* and *Planorbis* also common. Zygoptera, lepidoptera, chironomid, and polycentropodid caddis fly larvae were observed in this area as well.

Table 2.—North Branch, Waimakariri River.

SOURCE OF POLLUTION AND SAMPLING POINTS. Wastes from a large fellmongery. Locations are shown in Fig. 7.

DESCRIPTION. The stream is stable, flowing over a shingle and sand bottom approximately 15 to 25 ft wide in the stretch sampled. Aquatic weeds were abundant in many areas. Station 5 is in an area which is tidal but not saline. The Ohoka Stream is similar in character and about 8 feet wide where sampled. The Cust Main Drain flows over a more unstable shingle bed, subject to flooding. It is about 15 ft wide where sampled.

SAMPLING PERIODS. August 1956, February 1957. Dissolved oxygen data were supplied by the Government Analyst, Christchurch.

FISHERIES EVALUATION. The area below the fellmongery was examined for fisheries damage in August. Brown trout (*Salmo trutta*) were present, but very scarce in this area. Other species, however, were abundant: long- and short-finned eels (*Anguilla dieffenbachii, A. australis*), bullies (*Gobiomorphus* sp.), adult whitebait (*Galaxias attenuatus*), and an undetermined species of flounder.

The stream was re-examined in February 1957 and the following estimates of the trout population were made:

Station 1—42 lb/acre.
Station 3—practically nil (a few fingerlings)
Station 4—nil.

Eels, bullies, and adult whitebait were again very abundant at the two polluted stations.

Table 3.—Northbrook Drain.

SOURCE OF POLLUTION AND SAMPLING POINTS. Domestic sewage from a municipal septic tank discharge. Locations are shown in Fig. 7.

DESCRIPTION. The stream flows over a sand and shingle bottom with aquatic weeds abundant in many areas. The stream increases considerably in size over the stretch sampled with the entrance of tributaries. It is about 4 feet wide at Station 1 and about 12 ft wide at Station 7.

SAMPLING PERIODS. October 1956, February 1957, December 1957.

FISHERIES EVALUATION. The stream was examined for fisheries damage in December and the following estimates of the trout population were made:

Station 1—115 lb/acre.
Station 2—240 lb/acre.
Station 3— 85 lb/acre.

The trout taken from the two polluted stations appeared to be in healthy condition and ranged from 9 inches (probably yearlings) to 21 inches in length. Both long- and short-finned eels were abundant, particularly at Station 2.

Table 4.—Cam River

SOURCE OF POLLUTION AND SAMPLING POINTS. Wastes from a candied peel factory and a small septic tank. Locations are shown in Fig. 7.

DESCRIPTION. Stream is similar in size and character to the Northbrook Drain in the stretch sampled.

SAMPLING PERIOD. April 1957.

Table 5.—Mataura River.

SOURCE OF POLLUTION AND SAMPLING POINTS. At Gore, domestic sewage and wastes from an abattoir, a by-products factory, and a fellmongery. At Mataura, domestic sewage and wastes from a meat freezing works, a paper mill (no large-scale chemical pulp manufacture), and a dairy factory. At Wyndham, domestic sewage and wastes from a lactose-powder factory. Locations are shown in Fig. 8.

DESCRIPTION. The river is large and deep with recorded summer flows usually more than 150 cusecs, and flows at other periods many times this. Sampling was confined to marginal shingle areas.

SAMPLING PERIOD. April 1957.

Table 6.—Makarewa River.

SOURCE OF POLLUTION AND SAMPLING POINTS. Partially treated wastes from a meat freezing works at Makarewa. Station 1 is above the freezing works, Station 2 is about 250 yards downstream from the point of discharge, and Station 3 was at Wallacetown Bridge, approximately 3 miles downstream.

DESCRIPTION. The river is deep and fairly sluggish in the stretch sampled, flowing over a bottom of sand, shingle, and silt, with aquatic weeds abundant. Station 3 is near the upstream limit of tidal influence. The flow fluctuates widely with a minimum recorded summer flow of under 30 cusecs, and flows at other times much higher than that.

SAMPLING PERIOD. April 1957.

Table 7.—Manawatu River.

SOURCES OF POLLUTION AND SAMPLING POINTS. Effluent from municipal septic tanks at Palmerston North containing domestic sewage and, to a lesser degree, trade wastes. Domestic sewage from several minor sources. Dairy factory wastes above and below Palmerston North. Wastes from a meat freezing works below Palmerston North. Locations are shown in Fig. 9. (The sources of pollution of this river and the Oroua River are complex and are discussed in greater detail in the unpublished report by the Ministry of Works to the Pollution Advisory Council entitled "Pollution in the Lower Manawatu and Oroua Rivers".)

DESCRIPTION. The river is large, with low summer flow of about 400 cusecs and flows at other times much higher than this. Sampling was done at the margins of the shingle riffles, which were interspersed between long sluggish stretches in the area sampled.

SAMPLING PERIODS. Preliminary examination in November 1956. More detailed examination in March 1957 during peak production period at the freezing works.

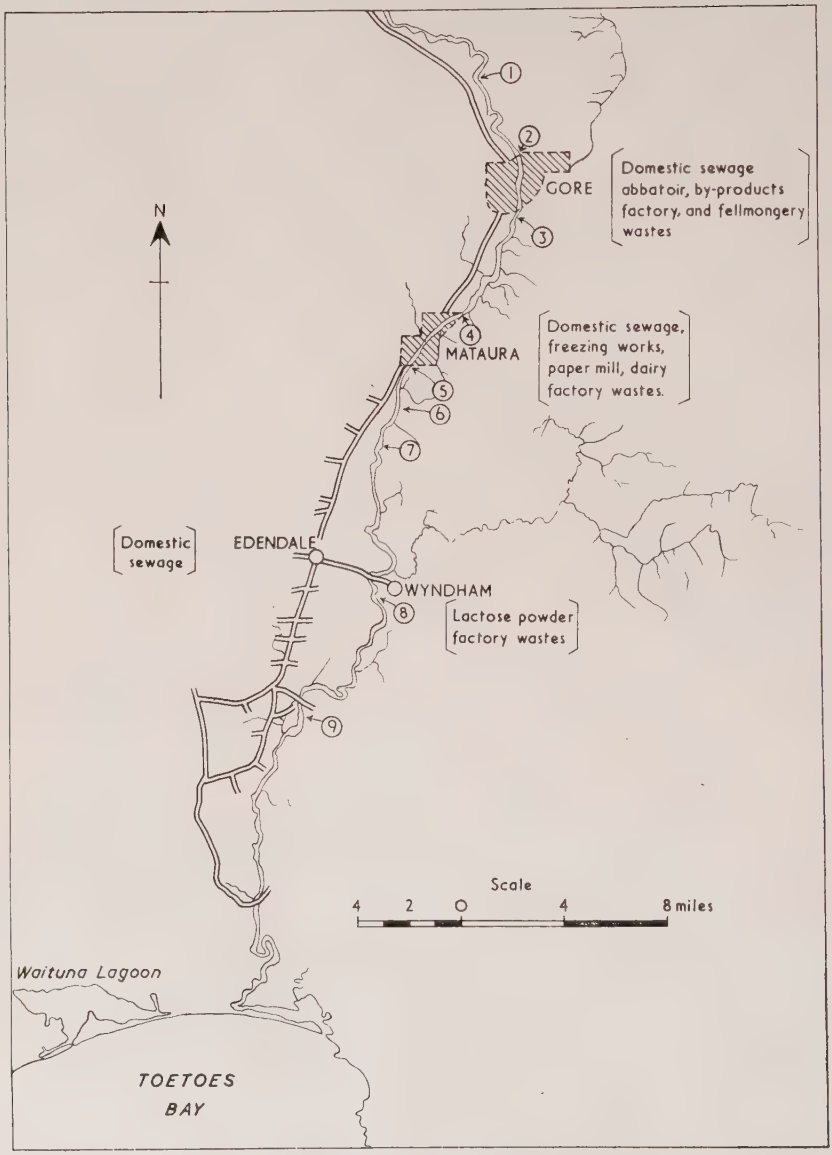

FIG. 8.—Map of Mataura River, showing numbered sampling points in relation to sources of pollution.

Table 8.—Oroua River.

SOURCE OF POLLUTION AND SAMPLING POINTS. Wastes from a meat freezing works at Feilding. Effluent from a municipal septic

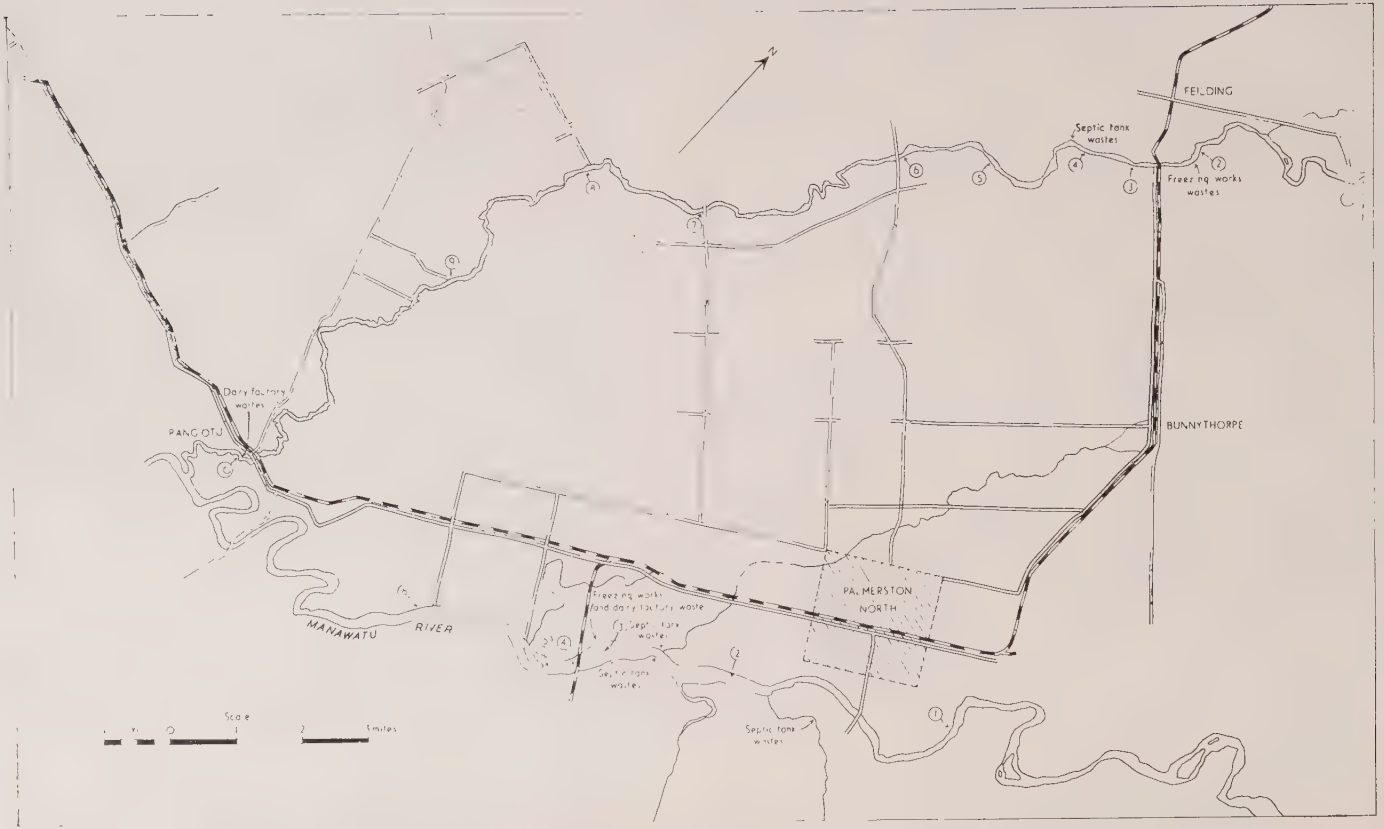

FIG. 9.—Map of Manawatu and Oroua Rivers showing numbered sampling points in relation to sources of pollution.

tank containing domestic sewage and wastes from an abattoir, wool-scour, boiling down works, and saleyard below this. Dairy factory wastes near Rangiotu. Locations are shown in Fig. 9.

DESCRIPTION. The river flows over an unstable braided shingle bed in the stretch sampled as far downstream as the vicinity of Kaimatarau Road, where it changes character. Here it is confined between stop-banks and the shingle is gradually replaced by sand. Summer low flows recorded in the river were usually over 65 cusecs.

SAMPLING PERIODS. Preliminary examination in November 1956. More detailed examination in March 1957 during peak production periods at the freezing works.

COMMENTS. The slight increase in organisms at Station 4 in March is unexplained. The fauna there was not typical of an area in which the stream was beginning to recover from pollution, in that organisms such as the mayflies and the hydropsychid caddis flies were better represented than the more tolerant forms, such as chironomids and oligochaetes. More typical recovery was observed farther downstream. In addition, a low dissolved oxygen value (1·8 p.p.m.) was recorded from this station. This suggests that the organisms were surviving in a localized pocket of relatively unpolluted water, such as an area where a small side channel entered. However, this assumption could not be confirmed.

Table 9—Huatoki Stream

SOURCE OF POLLUTION AND SAMPLING POINTS. Wastes from a dairy factory on Frankely Road. Station 1 is upstream from the discharge point, Station 2 25 yards below the discharge point, Station 3 about half a mile below the discharge point, and Station 4 about $1\frac{1}{4}$ miles below the discharge point.

DESCRIPTION. The stream is rapid, flowing over a boulder and shingle bottom about 6 ft wide at Station 1, increasing in size downstream to about 12 ft at Station 4.

SAMPLING PERIODS. November 1956, February 1957, October 1957. Sampling in November and October was done under conditions of high factory production; sampling in February was done under decreased production.

Table 10.—Kaupokonui Stream.

SOURCE OF POLLUTION AND SAMPLING POINTS. Wastes from a lactose-powder factory, dairy factories, and domestic sewage from a municipal septic tank. Locations are shown in Fig. 10.

DESCRIPTION. The stream is rapid, flowing over a boulder, shingle, and sand bottom. The flow at the mouth has been recorded as over 120 cusecs. The Mangawhero Stream, where sampled, is similar in size and character to the Kaupokonui. Dunns' Creek in its headwater

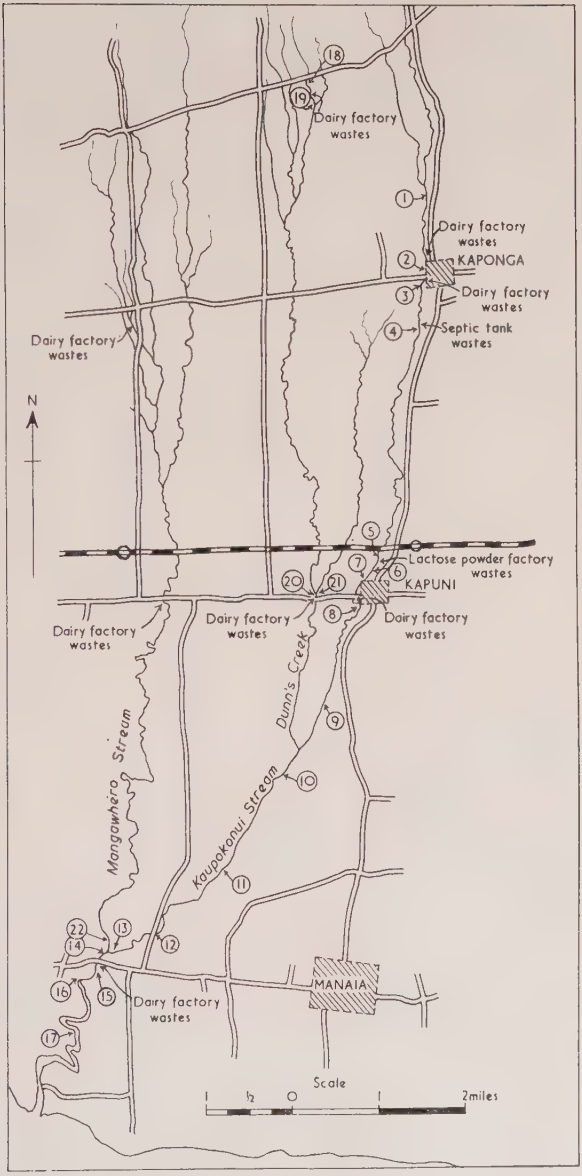

FIG. 10—Map of Kaupokonui Stream, showing numbered sampling points in relation to sources of pollution.

area (Stations 18, 19) is small and shallow, about 6 ft wide. Farther downstream (Stations 21, 22) the stream is larger, about 15 ft wide, and with a much greater volume of water.

Sampling Periods. Preliminary sampling above and below the lactose-powder factory in November 1956. More detailed sampling in February and October 1957. Factories were near peak production in November and October; sampling in February was done under decreased production.

Comments. Pollutional conditions below the lactose-powder factory just prior to February 1957 were reported to be the worst ever observed in this river.

Table 11.—Other Taranaki Streams

Six other Taranaki streams receiving dairy wastes were sampled in November 1956. No attempt was made to trace the extent of the pollution, but merely to determine the assemblages of fauna above and below the point of waste discharge.

Small Stream (A)

Source of Pollution and Sampling Points. Wastes from a dairy factory on Skeet Road west of Auroa. Station 1 is above the discharge point, Station 2 about 25 yards below the discharge point.

Description. The stream is a small, sluggish, weed-choked drain, about 5 ft wide.

Comments. There was visible evidence of gross pollution (at Station 2) and noxious odours were apparent. The dissolved oxygen here was found to be 0·2 p.p.m. The Zygoptera larva and amphipods which were collected at this station were found under the overhanging grassy banks. Neither group was found in sampling the open stream bed here.

Small Stream (B)

Source of Pollution and Sampling Points. Wastes from a dairy factory on Skeet Road at Auroa. Station 1 is above the discharge point, Station 2 about 25 yards below the discharge point.

Description. The stream is similar in size and character to Small Stream (A) but weeds were absent at Station 2.

Inaha Stream

Source of Pollution and Sampling Points. Wastes from a dairy factory on South Road east of Manaia. Station 1 was above the discharge point; station 2 about 10 yards below the discharge point.

Description. The stream is fairly deep and sluggish, flowing over sandy bottom, and about 15 ft wide where sampled.

Waiongana River

SOURCE OF POLLUTION AND SAMPLING POINTS. Wastes from a dairy factory near Devon Road south of Waitara. Station 1 is above the discharge point, Station 2 about 10 yards below the discharge point.

DESCRIPTION. The river flows over a shingle and boulder bottom, about 30 ft wide where sampled.

Otakeho Stream

SOURCE OF POLLUTION AND SAMPLING POINTS. Wastes from a dairy factory east of Auroa on Skeet Road. Station 1 is above the discharge point, Station 2 about 10 yards below the discharge point.

DESCRIPTION. The stream flows over a boulder and shingle bottom. A flow of approximately 30 cusecs has been recorded.

Kopoaiaia Stream

SOURCE OF POLLUTION AND SAMPLING POINTS. Wastes from a dairy factory at Pungarehu. Station 1 is above the discharge point, Station 2 about 10 yards below the discharge point, and Station 3 about 150 yards below the discharge point.

DESCRIPTION. The stream flows over a shingle and boulder bottom. It is similar in size to the Otakeho River.

Table 12.—Whakauru Stream

SOURCE OF POLLUTION. Wastes from a dairy factory at Tokoroa. Station 1 is above the discharge point and Station 2 about one mile below the discharge point. Shortly below this point the stream joins the Matarawa Stream. Station 3 is in the Matarawa Stream above the junction and Station 4 is 25 yards below the junction. Some slight pollution was reported to occur above Station 1, from a small slaughterhouse and a piggery.

DESCRIPTION. The Whakauru Stream flows over a sand bottom. It is about 6 ft wide where sampled. The Matarawa River flows over a sand bottom with abundant growths of aquatic weeds. It is about 12 ft wide where sampled.

SAMPLING PERIOD. November 1956.

Table 3.—Piako River

SOURCES OF POLLUTION AND SAMPLING POINTS. Domestic sewage from a municipal septic tank and wastes from four dairy factories. Locations are shown in Fig. 11.

DESCRIPTION. The Piako River is very sluggish in the stretch sampled, flowing over a predominantly sandy bottom. A low summer flow of about 3 cusecs has been recorded near Station 1 and a low flow of about 10 cusecs near Station 5. The flows are very much higher than this at other times. Growths of aquatic weeds were

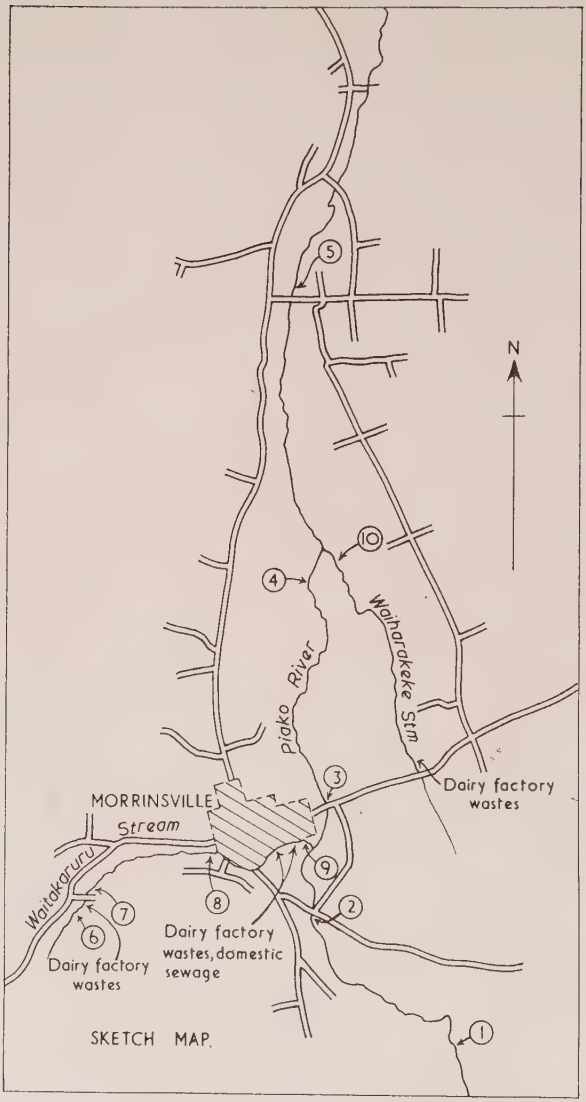

FIG. 11.—Map of Piako River and tributaries, showing numbered sampling points in relation to sources of pollution.

abundant at Stations 1 and 2, but absent farther downstream. The Waitakaruru Stream is similar in character to the Piako, with a recorded low flow of about 4 cusecs near its junction with that river.

The Waiharakeke Stream is a small, silt-bottomed drain where sampled, with a low flow of about $\frac{1}{2}$ cusec.

SAMPLING PERIOD. March 1957.

COMMENTS. The entire stretch of the Piako River sampled below Morrinsville was reported to be badly polluted, both from a visual and odour standpoint, about one month prior to sampling. The Piako River and its tributaries were sampled chemically in January 1958 and found to be devoid of oxygen, or nearly so at all stations below sources of pollution.

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TABLE 1.—South Branch, Waimakariri River: Quantitative Sampling (organisms per sq. ft), June 1956, March 1957.

STREAM	SOUTH BRANCH, WAIMAKARIRI RIVER							
STATION NO.	1		2		3		4	
SUBSTRATE	Sh, Sa		Sh,		Sh, Sa		Sh, Sa.	
MONTH	J	M	J	M	J	M	J	M
DISSOLVED OXYGEN (ppm.)	10.4	9.9	10.8	9.1				
WATER TEMPERATURE (°C)	8.5	16.0	9.0	15.0				
ALGAE	V	A	C	S	A	C	A	—
SEWAGE FUNGUS	—	—	—	—	A	S	S	—
EPHEMEROPTERA								
Deleatidium group	78	97	64	67	67	20	98	180
Coloboriscus humeralis	2	6	4	2	2	1	1	1
TRICHOPTERA								
Olinga group	107	96	11	23	64	39	95	38
Pycnocentrodes group	7	20	27	84	46	80	37	68
Hudsonema amabilis	2	3	1	1	2	2	13	2
Triplectides obsoleta	—	—	—	—	—	1	—	—
Hydrobiosis clavigera	—	—	1	1	—	—	—	1
H. frata	—	—	—	—	—	—	—	—
H. parumbripennis	3	1	2	1	1	—	5	2
H. umbripennis	—	—	—	—	—	—	1	—
Neurochorema confusum	17	—	2	1	9	1	4	—
Psilochorema bidens	—	1	1	3	2	1	2	3
Polycentropodidae	1	—	—	—	—	—	—	—
Hydropsychidae	34	14	9	9	6	2	16	2
Hydroptilidae	2	9	1	1	1	1	—	1
COLEOPTERA								
Hydora sp.	—	—	—	—	—	—	—	—
DIPTERA								
Chironomus zealandicus group	—	—	—	—	4	3	—	—
other Chironomidae	62	11	14	4	7	12	26	5
Austrosimulium tillyardi	—	—	—	—	—	—	—	—
Dixa sp.	8	—	—	—	—	—	—	—
Tipulidae	1	—	—	—	—	—	—	—
Psychodidae	—	—	—	—	—	—	—	1
Ceratopogonidae	—	—	—	—	—	—	—	—
COLLEMBOLA	—	—	—	—	—	—	—	—
PLECOPTERA								
Leptoperlidae	—	—	—	—	—	—	—	—
ODONATA								
Coenagriidae	—	—	—	—	—	1	—	—
LEPIDOPTERA	—	—	—	—	1	—	—	—
CRUSTACEA								
Paracalliope fluviatilis	29	2	2	1	2	—	1	1
Ostracoda	—	5	—	—	1	12	—	—
Hydracarina	—	—	—	—	—	—	—	—
MOLLUSCA								
Potamopyrgus badia	144	121	9	10	1860	1334	67	632
Physastra variabilis	3	9	—	1	19	60	—	13
Planorbis corinna	—	—	—	—	61	139	1	19
Pisidium novaezelandiae	—	—	—	—	83	256	—	2
Gundlachia lucasi	—	—	—	—	2	2	—	—
ANNELIDA								
Eiseniella tetraedra	—	1	—	3	—	—	—	1
Tubificidae	7	25	8	4	272	298	4	454
Naididae	—	3	—	1	—	1	—	—
Glossiphonidae	—	—	—	—	1	—	—	—
TURBELLARIA								
Curtisia stagnalis	—	—	—	—	25	22	1	—
Spathula fontinalis	1	2	1	—	—	—	—	—
Rhabdocoela	—	—	—	—	—	—	—	—
NEMATODA	2	—	—	—	1	1	—	—
TOTAL	510	426	157	216	2538	2288	370	1425

TABLE 1.—South Branch, Waimakariri River: Quantitative Sampling (organisms per sq. ft), June 1956, March 1957.

								Small Drain			Waimakariri River				
5		6		7		8		9	10		11		12		
Sh, Sa		D		D, Sl		Sl, Sa		D, Sa	Sl		Sh		Sh		
J	M	J	M	J	M	J	M	J	J	M	J	M	J	M	
11.2	7.7			8.2	6.7	8.4	4.9				12.5	9.0	12.4	4.8	
9.0	16.0				16.5	9.5	16.5				7.0	18.0	7.0	16.0	
A	C	C	C	C	C	C	C	—	—	—	S	S	A	A	
—	—	V	V	A	A	A	A	—	A	A	—	—	A	A	
154	70	—	—	—	—	—	—	—	—	—	18	32	39	16	
1	—	—	—	—	—	—	—	—	—	—	—	—	-	-	
50	39	—	—	—	—	—	—	—	—	—	—	—	—	—	
80	116	—	—	—	—	—	—	4	—	—	—	—	—	-	
12	5	—	—	—	—	—	—	—	—	—	—	—	—		
—	—	—	—	—	—	—	—	—	—	—	—	—	—		
—	2	—	—	—	—	—	—	—	—	—				-	
—	—	—	—	-	—	—	—	—	—	—	1	1	3	1	
2	—	—	—	—	—	—	—	—	—	—	—	—	-	-	
—	—	—	—	—	—	—	—	—	—	—	1	1	—	1	
6	3	—	—	—	—	—	—	—	—	—	—	—		—	
10	1	—	—	.	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
4	4	—	—	—	—	—	—	—	—	—	2	2	2	1	
7	2	—	—	—	—	—	—	—	—	—	—	1	—	—	
—	—	—	—	—	—	-	—	—	—	—	1	1	1	—	
—	—	18	1	—	—	13	—	80	1326	124	—	—	—	-	
36	19	—	—	—	—	2	—	—	—	—	—	4	1	1	
—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	5	—	—	—	—	1	1	1	1	
—	—	—	—	—	—	—	—	—	—	—		—	—	—	
—	—	—	—	—	—	—	—	2	—	—		—	-	—	
1	—	—	—	—	—	—	—	—	—	-	—	—	—	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	
—	-	—	—	—	—	—	—	—	—	—	—	—	—	—	
—	-	—	—	—	-	—	—	—	—	—	-	-	-	-	
12	2	—	—	—	—	—	—	2	—	—	—		-	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
182	68	—	—	—	—	—	—	18	—	—	—	—	-	—	
3	1	—	—	—	—	—	-	—	—	—	—	—	—		
1	2	—	—	—	—	—	-	—	-	—	—	—	—		
—	—	—	—	—	—	—	—	102	—	—	—	—	—	—	
-	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	-	—	—	—	-		—	
32	25	127	329	41	14	570	827	687	431	340	—	1	1	8	
—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	-	-	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	
—	—	22	4	—	—	55	—	—	—	—	—	—	—		
—	—	2	—	—	—	1	—	4	10	—	—		-	-	
596	360	169	334	41	14	645	827	899	1767	464	23	44	50	29	

TABLE 2.—North Branch, Waimakariri River and tributaries: Quantitative sampling (organisms per sq. ft.) August 1956, February 1957.

STREAM	NORTH BRANCH WAIMAKARIRI RIVER										OHOKA STREAM		CUST MAIN DRAIN	
STATION NO.	1		2		3		4		5		6		7	
SUBSTRATE	Sh, Sa		Sa, D, Sh		Sh, Sa		Sh		Sh		Sh Sa		Sh	
MONTH	A	F	A	F	A	F	A	F	A	F	A	F	A	F
DISSOLVED OXYGEN (ppm.)	9.4	9.7			9.5	8.7	9.4	8.1	9.8	8.1		9.5		
WATER TEMPERATURE (°C)	9.5	16.0			9.5	16.0	9.5	16.0	9.0	16.0		16.0		
ALGAE	S	A	—	—	V	A	A	A	A	S	S	—	C	A
SEWAGE FUNGUS	—	—	—	—	—	—	C	—	—	—	—	—	—	—
EPHEMEROPTERA														
Deleatidium group	58	91	31	14	2	1	—	—	8	2	84	70	58	134
Coloboriscus humeralis	1	1	1	—	—	—	—	—	—	—	2	—	—	1
TRICHOPTERA														
Helicopsyche sp.	63	4	16	—	—	—	1	5	10	—	110	—	166	4
Olinga group	225	33	20	2	—	—	165	16	7	2	101	14	55	7
Pycnocentrodes group	48	18	26	2	5	2	49	17	25	44	72	29	387	26
Hudsonema amabilis	1	—	9	5	—	—	8	8	3	2	4	—	7	1
Hydrobiosis clavigera	—	1	—	—	—	—	—	—	—	—	1	—	—	—
H. parumbripennis	—	5	1	2	—	—	—	—	—	—	3	1	—	—
Neurochorema confusum	—	3	—	—	—	—	—	—	—	—	5	3	1	1
Psilochorema bidens	1	1	3	4	—	—	—	2	—	—	1	2	1	1
P. leptoharpax	1	—	—	—	—	—	—	—	—	—	—	—	—	—
P. mimicum	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Hydropsychidae	13	14	1	—	—	—	—	—	—	—	41	1	1	15
Hydroptilidae	—	—	—	3	—	—	—	1	2	—	4	—	1	—
COLEOPTERA														
Hydora sp.	5	10	5	1	2	1	3	1	4	5	14	30	42	2
NEUROPTERA														
Archichauliodes dubitatus	—	—	—	—	—	—	—	—	—	—	—	—	—	2
DIPTERA														
Chironomus zealandicus group	—	—	17	1	1	—	—	—	4	—	—	—	—	—
Other Chironomidae	2	13	—	—	5	4	85	55	193	7	—	1	10	18
Austrosimulium tillyardi	—	—	—	2	—	—	—	—	—	—	1	2	1	8
Tipulidae	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Others	—	—	—	—	—	1	—	—	—	—	—	—	—	—
PLECOPTERA														
Eustheniidae	—	—	—	—	—	—	—	—	—	—	—	—	1	—
ODONATA														
Coenagriidae	—	—	—	—	—	—	—	—	—	—	1	—	—	—
CRUSTACEA														
Paracalliope fluviatilis	7	3	31	273	2	2	13	3	8	—	7	—	—	—
Ostracoda	—	1	—	11	—	—	—	—	—	—	—	—	—	—
Xiphocaris curvirostris	—	—	—	1	—	—	—	—	2	—	—	—	—	—
MOLLUSCA														
Potamopyrgus badia	112	197	371	201	169	133	126	314	8	2	33	4	1	1
Physastra variabilis	—	—	3	18	55	119	65	163	18	—	1	—	—	—
Planorbis corinna	—	—	—	—	—	1	—	16	2	—	—	—	—	—
Pisidium novaezelandiae	2	—	29	1	—	2	13	2	—	—	—	—	—	—
ANNELIDA														
Eiseniella tetraedra	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Tubificidae	11	8	78	11	160	171	1432	498	212	41	56	35	4	2
Naididae	—	7	—	2	—	—	—	—	16	2	—	—	—	—
Glossiphonidae	—	—	—	—	—	1	—	—	—	—	—	—	—	—
TURBELLARIA														
Curtisia stagnalis	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Spathula fontinalis	3	—	3	2	—	—	—	—	—	—	—	—	—	—
NEMATODA	1	—	1	2	—	1	—	—	—	—	—	—	—	—
TOTAL	552	410	646	596	401	439	1960	1101	522	107	541	192	736	224

TABLE 3.—Northbrook Drain: Qualitative Sampling, October 1956, February 1957, December 1957.

STATION NO.	1			2		3			4			5		6		7	
SUBSTRATE	Sh, Sa, D			Sh, Sa		Sh, Sa			Sh, Sa			Sh, Sa		Sh, Sa		Sh, Sa	
MONTH	O	F	D	O	F	O	F	D	O	F	D	O	F	O	F	O	F
DISSOLVED OXYGEN (ppm.)	8.6	7.9	8.5	7.6	4.7	8.2	5.6	7.7	8.2	6.2	8.2		5.9		6.1		6.9
WATER TEMPERATURE (°C)	13.0	15.0	12.0	13.5	15.0	13.5	15.0	14.0	13.0	16.0	14.0		15.0		15.0		15.0
ALGAE	—	—	—	C	—	C	—	C	A	A	A	S	A	—	—	—	—
SEWAGE FUNGUS	—	—	—	V	A	V	A	A	C	—	—	—	—	—	—	—	—
EPHEMEROPTERA																	
Deleatidium group	A	f	h	—	—	C	a	d	—	a	b	A	b	A	e	V	f
Coloboriscus humeralis	C	c	e	—	—	—	—	a	—	a	b	—	—	C	a	A	c
TRICHOPTERA																	
Helicopsyche sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	C	d
Olinga group	A	e	j	—	—	C	—	f	A	a	f	V	f	V	f	V	f
Pycnocentrodes group	C	d	b	—	—	S	—	a	V	f	c	V	g	C	h	—	c
Hudsonema amabilis	—	b	g	—	—	S	—	—	C	—	a	C	—	—	—	—	—
Triplectides obsoleta	—	b	c	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hydrobiosis parumbripennis	C	—	a	—	b	—	d	e	A	e	h	A	d	C	d	C	b
H. umbripennis	—	—	—	S	—	—	—	—	—	—	a	—	—	—	—	—	—
Neurochorema confusum	—	—	—	—	—	—	—	—	—	—	—	—	—	S	—	—	—
Psilochorema bidens	—	—	—	—	—	—	b	—	—	e	b	—	a	—	—	S	b
Polycentropodidae	—	b	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hydropsychidae	—	—	—	—	—	—	—	—	C	a	—	V	e	V	e	V	f
Hydroptilidae	—	—	—	—	—	—	—	—	—	b	b	C	—	—	—	—	—
COLEOPTERA																	
Hydora sp.	S	d	—	—	—		—	—	—	—	—		—		a	C	c
DIPTERA																	
Chironomus zealandicus group	—	—	—	—	—	—	—	a	—		—	—	—	—	—		
Other *Chironomidae*	A	b	f	V	j	V	i	i	V	b	j	C	a		b	—	—
Austrosimulium tillyardi	S	a	—	—	—	—	—	a	—	a	b		d	—	—		
Tipulidae	—	—	—	—	—	—	—	c	—	a	—	—	—	—	—	S	—
Others	—	—	—	—	a	—	—	—	—	—	—		b		—	—	—
CRUSTACEA																	
Paracalliope fluviatilis	A	h	f	—	c	—	g	—		e	—	A	i	C	—	C	e
Xiphocaris curvirostris	—	d	—	—	—	—	—	—	—	a	—	C		C	d	—	d
Isopoda	—	—	—	—	—	—	—	a	—	—	—	—	—	—	—	—	—
Ostracoda	—	a	a	—	—	—	—	—	—		—	S	—		—	—	—
MOLLUSCA																	
Potamopyrgus sp.	—	—	—	C	—	C	d	g	A	i	f	C	d	—	a	C	b
Physastra variabilis	—	—	—	C	c	C	e	g	C	i	g	A	i	C	—	C	—
Planorbis corinna	—	—	—	—	—	—	a	a	—	a	b	—	—	—	—	—	—
Pisidium novaezelandiae	—	e	a	—	—	—	b	f	—	—	—	A	b	A	—	—	b
ANNELIDA																	
Rhododrilus sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a
Tubificidae	C	g	b	V	i	V	j	j	V	j	j	V	f	V	e	A	f
Naididae	—	—	—	—	c	—	—	—	—	—	—	—	—		—	—	—
TURBELLARIA																	
Spathula fontinalis	—	c	—	S	—	—	c	—	C	f	—	S	d	S	d	A	b
Rhabdocoela	—	—	—	—	—	—	—	—	—	—	—	—	—	S		—	—

TABLE 4.—Cam River: Qualitative Sampling, April 1957.

STATION NO.	1	2	3
SUBSTRATE	Sh	Sh	Sa, Sh, W
ALGAE	—	V	S
SEWAGE FUNGUS	—	A	—
EPHEMEROPTERA			
Deleatidium group	g	d	e
Coloboriscus humeralis	f	a	d
TRICHOPTERA			
Olinga group	d	d	i
Pycnocentrodes group	g	—	—
Hudsonema amabilis	—	—	c
Hydrobiosis parumbripennis	b	d	f
Psilochorema bidens	—	—	d
P. mimicum	—	—	c
Hydropsychidae	c	a	—
Hydroptilidae	—	—	c
COLEOPTERA			
Hydora sp.	e	b	—
DIPTERA			
Chironomidae	—	f	—
Austrosimulium sp.	—	—	b
	a	—	—
CRUSTACEA			
Paracalliope fluviatilis	a	e	i
Ostracoda	—	—	a
MOLLUSCA			
Potamopyrgus badia	e	i	j
Pisidium novaezelandiae	b	f	—
ANNELIDA			
Eiseniella tetraedra	b	a	—
Lumbricus rubellus	—	a	c
Tubificidae	e	j	h
TURBELLARIA			
Spathula fontinalis	d	a	e
NEMATODA	a	—	—

TABLE 5.—Mataura River: Qualitative Sampling, April 1957

STATION NO.	1	2	3	4	5	6	7	8	9
SUBSTRATE	Sh	Sh, Bo	Sh, Bo	Sh	Bo	Sh, Bo	Sh, Bo	Sh, Bo	Sh
ALGAE	S	A	A	A	V	A	A	A	A
SEWAGE FUNGUS	—	—	—	—	B	S	—	—	—
EPHEMEROPTERA									
Deleatidium group	g	f	f	g	—	f	g	h	g
Nesameletus sp.	b	—	a	—	—	a	—	-	—
TRICHOPTERA									
Beraeoptera sp.	—		—	a	—	—		—	—
Olinga group	b	—	a	—	—	—		a	c
Pycnocentrodes group	d	d	b	—	—	—	—	b	c
Hudsonema amabilis	d	—	b	—		—	—	a	b
Costachorema xanthoptera	—	b	—	—	—		—	-	—
Hydrobiosis clavigera	b	—	—	—	—	—	—	—	—
H. parumbripennis	—	a	b	—	b	—	—	b	—
H. umbripennis	—	-	—	—	a	b	—	—	—
Psilochorema leptoharpax	a	—	—	—	—	—	—	—	—
Psilochorema sp.	—	—	a	—	—	—		—	—
Hydropsychidae	—	d	e	e	—	c	—	g	c
Hydroptilidae		-	c	--	—	b	-	-	b
COLEOPTERA									
Hydora sp.	f	g	g	g	g	c	c	g	h
Other	-	—	—	—	—	—	—	—	a
DIPTERA									
Chironomidae	a	f	i	g	j	e	f	e	c
Austrosimulium laticorne	—	c	b	b	—		—	b	
Tipulidae	—	—	b	a	b	—	—		
Ephydridae	—	-	b	—	f	—	—	—	—
PLECOPTERA									
Leptoperlidae		—	—	—	—		a	—	—
	—	—	—	—	—			-	—
CRUSTACEA									
Paracalliope fluviatilis	b	—	—	-	—	a	—		i
Ostracoda	—	—	—	—	—	a	—	—	--
MOLLUSCA									
Potamopyrgus antipodum	g	a	b	—	c	g	d	f	h
Physastra variabilis	—	—	a	—	—	a	—	—	a
Planorbis corinna	—	--	b	—	—	e	b	--	a
Pisidium novaezelandiae	—	—	-	—	—	—		—	b
ANNELIDA									
Eiseniella tetraedra	b	—	c	a	b		—	a	—
Tubificidae	d	-	e	e	h	i	f	j	f
Naididae	—	—	—	—	—	c	—	b	—
TRICLADIDA									
Dugesia montana	—	b	c	b	—		—	c	b

TABLE 6.—Makarewa River, Qualitative Sampling, April 1957.

STATION NO.	1	2	3
SUBSTRATE	Sh, Sa, Si, W	Sh, Sa, Si, W	Sh, Sa, Si, W
ALGAE	A	A	A
SEWAGE FUNGUS	—	A	C
EPHEMEROPTERA			
Deleatidium group	f	—	a
TRICHOPTERA			
Hudsonema amabilis	b	—	—
Hydropsychidae	b	a	—
Hydroptilidae	—	—	b
COLEOPTERA			
Hydora sp.	—	a	—
DIPTERA			
Chironomus zealandicus group	—	b	—
Other Chironomidae	a	f	—
Austrosimulium australense	b	—	—
Stratiomyiidae	a	—	—
CRUSTACEA			
Paracalliope fluviatilis	h	e	e
Ostracoda	—	d	—
MOLLUSCA			
Potamopyrgus badia	f	f	i
Physastra variabilis	c	b	f
Pisidium novaezelandiae	f	—	e
Gundlachia lucasi	—	—	c
ANNELIDA			
Eiseniella tetraedra	a	—	—
Tubificidae	f	i	g
TRICLADIDA			
Curtisia stagnalis	—	b	d
Dugesia montana	b	—	—
NEMATODA	a	—	—

TABLE 7.—Manawatu River: Qualitative and Quantitative Sampling (Organisms per sq. ft), November 1956, March 1957.

STATION NO.	1			2		3		4			5		6		
SUBSTRATE	Sh			Sh		Sh		Sh			Sh		Sh	Sh, Sa	
MONTH	N	M		M		M		N	M		M		N	M	
DISSOLVED OXYGEN (ppm.)	9.8	9.0		9.1		10.5		9.4	10.3		9.6		9.8	9.4	
WATER TEMPERATURE (°C)	20.0	20.5		20.5		22.0		20.0			21.5			22.0	
ALGAE	C	A		A		A		C	A		A		A	A	
SEWAGE FUNGUS	—	—		—		C		—	A		C		—	C	
*TYPE OF SAMPLE	Q	Q	F	Q	F	Q	F	Q	Q	F	Q	F	Q	Q	F
EPHEMEROPTERA															
Deleatidium group	h	h	49	h	38	f	44	c	d	4	f	19	g	f	154
Coloboriscus humeralis	—	b	1	c	—	a	2	—	—	—	—	1	—	a	—
TRICHOPTERA															
Pycnocentrodes group	f	b	—	c	2			c	—	2	b	3	b	a	1
Hudsonema amabilis	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hydrobiosis umbripennis	b	d	1	d	2	b	4	b	a	1	b	1	a	b	1
Psilochorema sp.	a	—	—	—	1	—	1	—		—		1	—		1
Hydropsychidae	e	g	4	f	19	f	14	a	a	11	d	16	b	d	14
Hydroptilidae	c	a		a	1		-			1	—	-		—	1
COLEOPTERA															
Hydora sp.	f	h	8	g	20	e	21	c	f	64	h	242	d	g	146
NEUROPTERA															
Archichauliodes dubitatus	b	—	—	a	—	—	—	a			—	1		a	
DIPTERA															
Chironomus zealandicus group	—	—	—	—	—	—	2	b	c	32	b	6		e	1
Other *Chironomidae*	g	g	1	e	—	h	42	f	h	273	g	47	f	d	39
Austrosimulium tillyardi	—	—	—	—	—	—	—	—	—	—	—	—	a	—	-
Tipulidae	b	b	—	—	1	—	4	—	—	1	—	—	—	—	1
Ephydridae	—	—	—	—	—	—	—	—	—	—	—	—	—	a	
PLECOPTERA															
Leptoperlidae	a	—	—	—	—	—	—	—	—	—	—	—			
CRUSTACEA															
Xiphocaris curvirostris	—	—	—	a	—	-	—	—	—	—	—	-			
MOLLUSCA															
Potamopyrgus corolla	b	f	2	a	1	-	-	-		1	—	1	—	b	2
Physastra variabilis	—	—	—	—	-	—	-	-			—	-			1
ANNELIDA															
Eiseniella tetraedra	—	—	—	—	—	—	—	—		—	a	-	-	-	1
Tubificidae	—	—	1	—	—	—	3	—	c	19	f	9	-	f	74
Naididae	—	b	—	a	1	a	3	—	—	34	e	5	-	e	2
TURBELLARIA															
Dugesia sp.	a	—	—	—	—	—	—								
NEMATODA	-			-		—	-			—	a	-			
TOTAL			66		86		140			443		352			439

* Q — Qualitative F — Organisms per sq. ft.

TABLE 8.—Oroua River: Qualitative and Quantitative Sampling (Organisms per sq. ft). November 1956, March 1957.

STATION NO.	1			2		3			4	
SUBSTRATE	Sh			Sh		Sh			Sh	
MONTH	N	M		M		N	M		M	
DISSOLVED OXYGEN (ppm.)	8.8	9.2		9.1		8.6	3.8		1.8	
WATER TEMPERATURE (°C)		21.5		23.5		20.0	25.5		25.5	
ALGAE	—	C		C		—	C		C	
SEWAGE FUNGUS	—	—		—		—	B		B	
TYPE OF SAMPLE*	Q	Q	F	Q	F	Q	Q	F	Q	F
EPHEMEROPTERA										
Deleatidium group	f	g	82	g	84	c	b	3	d	15
Coloboriscus humeralis	b	c	1	—	1	—	—	—	—	—
TRICHOPTERA										
Pycnocentrodes group	e	b	2	a	2	—	—	—	—	—
Costachorema xanthoptera	—	—	—	—	—	—	—	—	—	—
Hydrobiosis umbripennis	a	a	—	—	1	d	—	—	—	—
Psilochorema sp.	—	a	1	a	—	—	—	—	—	—
Hydropsychidae	b	c	4	d	13	b	—	—	a	8
COLEOPTERA										
Hydora sp.	e	f	43	e	19	e	a	4	e	16
DIPTERA										
Chironomus zealandicus group	—	—	—	—	—	—	—	—	—	—
Other Chironomidae	d	e	—	g	11	g	c	4	d	4
Austrosimilium tillyardi	—	—	1	—	—	—	—	—	—	—
Tipulidae	—	—	1	a	1	—	—	—	—	—
Psychodidae	—	—	—	—	—	—	—	—	—	—
Ephydridae	—	—	—	—	—	—	—	—	—	—
PLECOPTERA										
Leptoperlidae	a	—	—	—	—	—	—	—	—	—
HEMIPTERA										
Corixidae	—		—	—	—	—	—	—	—	—
CRUSTACEA										
Paracalliope fluviatilis	—	—	—	—	—	—	—	—	—	—
Ostracoda	—	—	1	—	—	—	—	—	—	—
MOLLUSCA										
Potamopyrgus sp.	—	—	1	b	4	—	—	—	—	—
Physastra variabilis	—	—	—	—	—	—	—	—	—	—
Planorbis corinna	—	—	—	—	—	—	—	—	—	—
ANNELIDA										
Tubificidae	a	—	—	—	—	c	a	4	a	2
Naididae	—	—	—	—	1	—	—	1	—	—
NEMATODA	—	a	—	—	—	—	—	—	—	—
TOTAL			137		137			16		45

Q — Qualitative F — Organisms per sq. ft.

TABLE 8.—Oroua River: Qualitative and Quantitative Sampling (Organisms per sq. ft). November 1956, March 1957.

5			6			7			8		9		10	
Sh			Sh			Sh, Sa			Sh, Sa		Sa, Sh		Sa	
N	M		N	M		N	M		M		M		M	
8.6	4.4		9.2	11.6		8.8	9.4		12.3		6.3		5.6	
20.0	25.5		21.5	20.5		21.0	20.5		23.0		21.5		21.5	
S	V		S	A		S	A		A		S		S	
—	B		—	A		—	C		C		S		S	
Q	Q	F	Q	Q	F	Q	Q	F	Q	F	Q	F	Q	F
c	—	—	d	—	—	e	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	b	—	—	e	—	—	—	—	—	—	—	—
—	—	—	—	—	—	a	—	—	—	—	—	—	—	—
—	—	—	—	—	—	c	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
b	—	—	d	—	—	e	d	15	e	48	c	14	—	1
b	—	1	d	—	—	d	—	3	c	3	—	1	—	5
g	—	1	h	—	1	h	b	2	c	7	g	1	d	12
—	—	—	—	—	—	a	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	1	—	—	1	—	—	—	—	—	—	—	—	—
—	—	—	c	—	—	b	—	3	b	2	—	1	—	—
—	—	—	—	—	—	a	—	—	—	—	—	—	—	—
		—					—	1	—	1	b	—	—	2
—	—	—	b	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	1	a	—	—	—
—	—	—	—	—	—	—	—	—	b	1	—	—	—	—
—	—	—	—	—	2	—	a	1	—	1	—	—	—	—
c	b	8	d	b	5	f	f	12	f	76	g	107	f	55
h	—	3	i	—	1	f	d	5	g	90	e	17	—	7
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		15			10			42		230		141		82

Q — Qualitative F — Organisms per sq. ft.

TABLE 9.—Huatoki Stream: Qualitative Sampling, November 1956, March 1957, October 1957.

STATION NO.	1			2			3			4		
SUBSTRATE	Sh, Sa			Sh, Bo			Sh, Bo			Sh, Bo		
MONTH	N	M	O	N	M	O	N	M	O	N	M	O
DISSOLVED OXYGEN (ppm.)		8.9	11.0		7.7	9.8		3.3	6.4		8.7	9.4
WATER TEMPERATURE (°C.)		16.5	11.5		17.0	11.5		18.5	11.5		19.0	12.0
ALGAE	—	—	C	—	—	—	—	S	C	—	S	V
SEWAGE FUNGUS	—	—	—	B	B	B	B	B	B	—	—	V
EPHEMEROPTERA												
Deleatidium group	V	g	g	C	a	c	C	—	—	V	f	h
Coloboriscus humeralis	A	d	g	—	—	a	—	—	—	C	—	—
Nesameletus sp.	A	e	g	C	—	d	C	—	—	A	b	f
Ichthybotus sp.	—	—	—	—	—	—	—	—	—	—	a	—
TRICHOPTERA												
Olinga group			c		—	—	—	—	—	V	a	e
Pycnocentrodes group		—	b	—	—	—	—	—	—	A	a	g
Hudsonema amabilis	—	—	—	—	—	—	—	—	—	C	—	a
Hydrobiosis parumbripennis	S	—	b	—	—	—	S	—	—	C	e	d
Hydrobiosis sp.	—	b	a	—	—	—	—	—	—	—	—	—
Pslichorema sp.	—	—	—	—	—	a	—	—	—	C	c	c
Other Rhyacophilidae	—	—	—	—	—		—	—	—	—	—	a
Polycentropodidae	—	—	—	—	—	a	—	—	—	—	b	d
Hydropsychidae	C	c	f	C	—	—	C	—	—	A	—	—
Hydroptilidae	S	—		—	—	—	—		—	—	b	c
COLEOPTERA												
Hydora sp.	C	—	b	—	—	—			—	S	a	c
Others	S	a	c	—	—	—	—	—	—	S	—	—
NEUROPTERA												
Archichauliodes dubitatus	C	b	e	—	—	—	—		—	—	a	—
DIPTERA												
Chironomus zealandicus group			—	C	i	a	C	f	f	—	—	—
Other Chironomidae	S		b	A	c	i	C	b	a	A	b	h
Austrosimulium australense	—	c	a	—	a	—	S	—	—	—	f	a
Tipulidae		—	a	—	—	—	—	—	—	A		d
PLECOPTERA												
Leptoperlidae			c			—			—		—	a
CRUSTACEA												
Ostracoda		—	—			—	—			—		a
MOLLUSCA												
Potamopyrgus sp.	—	—	—		—		S	—	—	—	i	d
Pisidium novaezelandiae	—	—	—		—	—	—	—	—	—	—	a
Gundlachia neozelanica	—	—	b	—	—	—	S	—	—	—	e	—
ANNELIDA												
Eiseniella tetraedra	—	—	—	—	—	—	—	—	—	S	—	—
Tubificidae	—	d	b	V	g	j	V	f	j	C	e	g
Naididae	—	—	—	—	—	—	—	b	—	—	b	f
TURBELLARIA												
Spathula fontinalis	—	—	b	—	—	—	—	—	—	—	b	b

Table 10.—Kaupokonui Stream: Qualitative Sampling: November 1956, March 1957, October 1957.

River	Kaupokonui stream																													Dunn's Creek			Manga-whero Stream
Station	1	2	3	4	5			6			7			8		9		10	11		12		13		14		15	16	17	18	19	20	21	22
Bottom Material	Bo, Sh	Bo,Sh	Bo, Sh	Bo, Sh	Bo, Sh, Sa			Bo, Sh, Sa			Bo, Sh			Bo, Sh		Bo, Sh		Sh, Bo Sa	Sh, Bo		Sh,Bo		Sh, Bo Sa		Sh, Bo Sa		Sh, Bo Sa	Sh, Bo Sa	Sh, Bo Sa	Bo, D Si	Bo, D Si	Sh, Sa	Sh, Sa	Bo, Sh
Month	M	M	M	M	N	M	O	N	M	O	N	M	O	M	O	M	O	M	M	O	M	O	M	O	M	O	M	M	M	M	M	M	M	M
Dissolved Oxygen (ppm.)	7.9	9.2	8.8	8.3		8.7	10.5		7.3	7.9		2.2	9.2	4.1	9.3	9.3	10.0	10.0	9.0	10.1	8.9	10.0	9.3	10.0	9.4	10.0	8.3	8.6	8.5	7.8	4.8	8.2	8.3	9.2
Water temperature (°C)	16.0	19.0	17.5	17.0		20.5	9.0		28.5	13.0		19.0	10.5	19.0	11.0	20.5	11.0	21.5	21.0	13.5	21.0	12.0	22.0	12.0	20.0	11.5	19.5	20.0	21.0	16.0	16.0	17.0	17.0	19.5
Algae	S	S	A	V	—	V	C	—	C	C	V	C	C	C	C	V	A	V	V	A	V	A	A	C	A	C	A	A	A	—	—	C	C	A
Sewage Fungus	—	S	S	S	—	—	—	B	B	B	A	B	B	B	B	—	V	—	—	—	—	—	—	—	—	—	A	C	—	—	B	—	—	—
Ephemeroptera																																		
Deleatidium group	h	e	i	f	V	h	j	—	a	a	A	—	c	—	e	a	e	a	d	e	d	e	c	g	e	g	—	d	e	h	—	g	g	g
Coloboriscus humeralis	e	—	b	—	A	—	d	—	—	a	—	—	—	—	a	—	—	—	—	b	—	a	—	—	—	a	—	b	b	b	—	—	—	—
Nesameletus sp.	f	c	e	g	S	b	c	—	—	—	—	—	a	—	—	—	a	—	—	b	—	a	—	b	—	—	—	—	—	d	—	b	—	—
Trichoptera																																		
Beraeoptera roria	g	h	h	h	—	a	b		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Helicopsyche sp.	f	c	b	a	—	—	a		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	j	h	—
Olinga group	d	e	f	c	—	c	b		—	—	—	—	—	—	—	—	—	—	—	d	a	e	—	c	c	d	b	c	b	—	—	g	g	f
Pycnocentrodes group	e	c	f	h	V	j	h	A	—	e	C	—	a	—	—	—	b	d	g	j	g	i	g	h	j	j	e	h	j	—	—	h	g	i
Hudsonema amabilis	—	b	c	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	—	a	—	a	—	—	—	—	—	—	—	g	d	—
Costachorema xanthoptera	a	—	—	—	—	—	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hydrobiosis clavigera	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
H. parumbripennis	d	d	d	c	c	d	d	—	—	—	—	—	—	—	—	a	a	—	b	a	c	b	b	d	a	a	—	a	c	—	—	—	d	a
H. umbripennis	—	—	—	—	—	a	—	—	—	—	—	—	—	—	—	d	d	d	d	f	d	f	a	d	a	c	—	c	—	—	—	—	b	—
Hydrobiosis sp.	—	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	—	—	—	—	—
Neurochorema confusum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	—	—	—	—	—
Neurochorema sp.	b	c	c	d	—	a	b	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	b	—	a	b	—	—	—	a	a	c
Psilochorema leptoharpax	—	—	—	a	—	a	b	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Psilochorema mimicum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	—	—	—	—	—
Psilochorema sp.	b	b	a	c	—	c	—	—	—	a	—	—	a	—	a	—	b	—	c	c	c	c	b	—	—	c	—	a	a	—	—	—	e	b
Synchorema sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	—	—	—	—	—	—
Other Rhyacophilidae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	b	—	a	—	—	—	—	—	a	—	—	—	—	—	—
Polycentropodidae	—	—	—	b	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	—	—	—	—
Hydropsychidae	e	d	e	b	S	f	b	—	—	—	—	—	—	—	—	a	—	b	f	h	f	i	g	f	g	e	c	f	g	—	—	a	d	f
Hydroptilidae	—	g	—	a	—	e	—	—	—	—	—	—	—	—	—	—	—	d	—	d	—	—	—	—	a	a	a	b	a	—	—	b	b	b
Coleoptera																																		
Hydora sp.	f	c	d	d	C	g	g	—	a	—	S	—	—	—	—	—	b	f	e	e	f	e	f	f	g	—	d	g	h	a	—	g	h	h
Neuroptera																																		
Archichauliodes dubitatus	e	b	b	b	S	c	b	—	—	—	—	—	b	—	—	—	—	b	b	e	b	d	b	c	a	b	a	c	b	—	—	b	b	d
Diptera																																		
Chironomus zealandicus group	—	a	a	c	—	—	—	—	d	—	—	h	—	h	—	i	—	c	b	—	—	—	—	—	—	—	a	—	—	—	b	e	c	b
Other Chironomidae	f	j	j	h	—	h	i	V	b	j	V	c	h	—	h	e	j	f	h	j	f	j	b	h	b	c	c	f	c	—	e	c	f	e
Austrosimulium australense	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	a	—	—	b	—	—	a	b	—	—	—	—	—	a
Tipulidae	e	d	d	—	S	e	d	S	b	—	S	—	—	—	—	—	b	—	c	c	b	c	a	a	a	c	a	a	a	a	—	b	d	a
Ephydridae	b	—	—	—	—	—	—	—	—	—	—	d	—	—	—	—	—	b	—	—	—	—	a	—	—	—	—	—	—	—	—	—	—	—
Psychodidae	—	d	—	d	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	b	—
Others	—	a	—	—	S	—	b	—	—	a	—	—	—	—	—	—	—	—	—	b	—	b	—	—	—	b	—	—	—	—	—	—	—	—
Collembola	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	—	—	—	—
Plecoptera																																		
Eustheniidae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	—	—	—	—	—	—	—	—
Leptoperlidae	—	—	—	—	—	—	d	—	—	—	—	—	a	—	—	—	a	—	—	b	—	—	—	—	—	c	—	—	—	—	—	—	—	—
Hemiptera																																		
Corixidae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	—	f	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lepidoptera	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	—	—	—	—	—	—	—
Crustacea																																		
Paracalliope fluviatilis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a
Ostracoda	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	b	—	—	—	—	a	—	—	—	—	—	c	—	—	—	—	—	—	a
Xiphocaris curvirostris	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	b
Paranephrops sp.	—	—	—	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	—	—	—	—
Mollusca																																		
Potamopyrgus sp.	—	b	a	a	C	f	g	S	f	—	—	—	—	—	—	b	g	i	h	i	j	j	i	i	i	g	i	i	—	—	—	—	—	—
Planorbis corinna	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	e	—	h	f	—	d	—	—	—	—	—	—	—	b	—	—	—	—	—
Pisidium novaezelandiae	—	—	—	—	—	—	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	a	—	—
Gundlachia neozelanica	—	—	—	b	—	—	—	—	—	—	—	—	—	—	—	d	—	f	—	—	—	—	—	—	—	—	c	d	c	—	—	h	—	a
Annelida																																		
Eiseniella tetraedra	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	d	—	a	—	—	—	—	—	—	—	—	—	—
Tubificidae	—	—	—	b	—	a	b	A	h	f	A	g	h	h	i	j	j	h	d	h	e	i	e	f	j	b	e	l	c	—	—	s	c	—
Naididae	b	g	g	i	—	h	f	—	j	a	—	h	e	h	g	f	i	a	a	g	—	b	i	—	—	l	—	—	—	—	—	s	c	—
Glossiphonidae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	b	—	a	d	—	—	—	—	—	—	—	—	—	—	—	—	—
Turbellaria																																		
Curtisia stagnalis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	f	c	b	e	—	f	—	d	—	g	e	c	—	—	a	—	b
Rhabdocoela	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	b

TABLE 12.—Whakauru and Matarawa Streams: Qualitative Sampling, November 1956.

STREAM	WHAKAURU STREAM		MATARAWA STREAM	
STATION NO.	1	2	3	4
SUBSTRATE	Sa, D	Sa, W	Sa, W	Sa, W
ALLGAE	C	C	A	A
SEWAGE FUNGUS	—	—	—	—
EPHEMEROPTERA				
Deleatidium group	A	S	A	V
Coloboriscus humeralis ..	S	—	C	S
Nesameletus sp.	C	—	—	—
TRICHOPTERA				
Olinga group	—	—	C	—
Pycnocentrodes group	—	—	—	C
Hudsonema amabilis	—	—	C	—
Triplectides obsoleta	C	—	—	—
Hydropsychidae	C	—	C	A
Hydroptilidae	—	—	—	C
COLEOPTERA ..				
Hydora sp.	—	—	C	—
DIPTERA				
Chironomus zealandicus group ..	C	C	—	C
Other Chironomidae	C	V	A	V
Austrosimulium australense ..	S	—	—	S
Others	S	S	—	—
PLECOPTERA				
Leptoperlidae	S	—	—	S
MOLLUSCA				
Potamopyrgus antipodum ..	—	V	—	A
ANNELIDA				
Eiseniella tetraedra	—	S	C	S
Tubificidae	—	V	C	V
Naididae	S	S	—	—
TURBELLARIA				
Planariidae	—	—	S	S

TABLE 13.—Piako River and tributaries: Qualitative Sampling, March 1957.

STREAM	PIAKO RIVER						WAITAKARURU STREAM			WAIHARA-KEKE STREAM
STATION NO.	1		2	3	4	5	6	7	8	9	10
SUBSTRATE	Sa, Si, D	W	Be, W	Sa, Sl	Sa	Sa	Sa	Sl, Bo	Sa, Be Sl	Sl, D	Sl
ALGAE	V		V	A	C	—	V	C	A	C	C
SEWAGE FUNGUS	—		—	C	—	—	—	A	C	V	—
EPHEMEROPTERA											
Deleatidium group	—	—	g	—	—	—	a	—	—	—	—
TRICHOPTERA											
Olinga group	—	—	e	—	—	—	—	—	—	—	—
Hydroptilidae	a	f	c	—	—	—	b	—	—	—	—
COLEOPTERA											
Dytiscidae	—	—	—	—	—	d	—	—	—	—	—
DIPTERA											
Chironomus zealandicus group	—	—	—	—	—	d	—	b	—	f	—
Other Chironomidae	—	b	d	—	—	—	—	—	—	—	—
Austrosimulium australense	—	—	g	—	—	—	c	—	—	—	—
Culex pervigilans	—	—	—	—	—	b	—	—	—	—	—
ODONATA											
Coenagriidae	—	c	—	—	—	—	—	—	—	—	—
HEMIPTERA											
Corixidae	a	c	—	a	—	a	—	—	—	—	—
LEPIDOPTERA	—	c	—	—	—	—	—	—	—	—	—
CRUSTACEA											
Paracalliope fluviatilis	—	j	i	—	—	—	f	—	—	—	—
Ostracoda	—	—	—	—	—	a	—	—	—	—	—
MOLLUSCA											
Potamopyrgus corolla	g	h	j	—	—	h	f	—	—	—	—
Pisidium novaezelandiae	—	—	—	—	—	—	b	—	—	—	—
ANNELIDA											
Tubificidae	d	a	d	j	i	j	c	j	j	j	j
Glossiphonidae	a	a	c	—	—	—	—	—	—	—	—
TURBELLARIA											
Curtisia stagnalis	—	—	c	—	—	—	—	—	—	—	—

A RECONNAISSANCE SURVEY OF POLLUTION IN THE MANAWATU RIVER

By J. K. Johannesson, Wellington City Council Laboratory, Wellington

(Received for publication, 15 May 1958)

Summary

A survey has been made of pollution in the Manawatu River over 24 hours at a time of lowest flow in midsummer (1957), the sampling sites ranging from Palmerston North to Foxton ocean beach. Counts of *Escherichia coli*, type 1, were high near the Palmerston North sewer outfall, but low at Shannon. Local pollution was observed at Foxton, but no pollution was found at Foxton ocean beach.

Oxygen analyses revealed a typical dissolved oxygen sag curve down river, but the lowest values found were not critical and recovery was complete.

A pronounced photosynthetic contribution to the re-oxygenation was observed during the hours of daylight.

Introduction

The Manawatu River arises in southern Hawke's Bay, flows through the Manawatu Gorge, then meanders across the Manawatu Plains, and reaches the sea at Foxton. Numerous small streams and the tributary rivers Tirimea, Mangatainoka, Mangahao, Pohangina, and Oroua join the Manawatu along its length. In the Hawke's Bay area are the towns of Dannevirke, Woodville, and Pahiatua, and in the Manawatu, the city of Palmerston North and the towns of Ashhurst, Feilding, Shannon, and Foxton. The Manawatu River receives sewage effluent from most of the above towns, including Feilding, which discharges its sewage into the Oroua River. Also contributing to the pollution of the river are two large meat works, one at Longburn, eight miles from Palmerston North, and one at Aorangi, which discharges into the Oroua adjacent to Feilding. Various dairy factories and other works also make a small contribution. The Manawatu River in its lower reaches is a tidal estuary with mud flats, and only up towards Palmerston North is shingle to be found on the river side and bottom.

In 1956, the Palmerston North City Council, concerned with the possible effect of their sewage discharge upon the condition of the river and the creation of a possible risk to bathers at Foxton Ocean Beach, situated at the mouth of the river, decided that a pollution survey of the river was desirable. The author of this paper was requested to give scientific advice and assistance. An investigation was arranged to provide a reconnaissance survey of the degree of pollution of the river under conditions of minimum flow, which was then considered to be of the order of 400 cusecs. It was known from the literature that the critical period for oxygen content is during the night hours, when photosynthetic action ceases to provide aeration of the water, and the

algae involved become oxygen absorbers and enhance the deoxygenation of the pollutional load. Consequently, it was decided to take samples throughout a complete 24-hour period at each sampling site.

Figure 1 is a sketch map of this area showing the various outfalls and sampling sites.

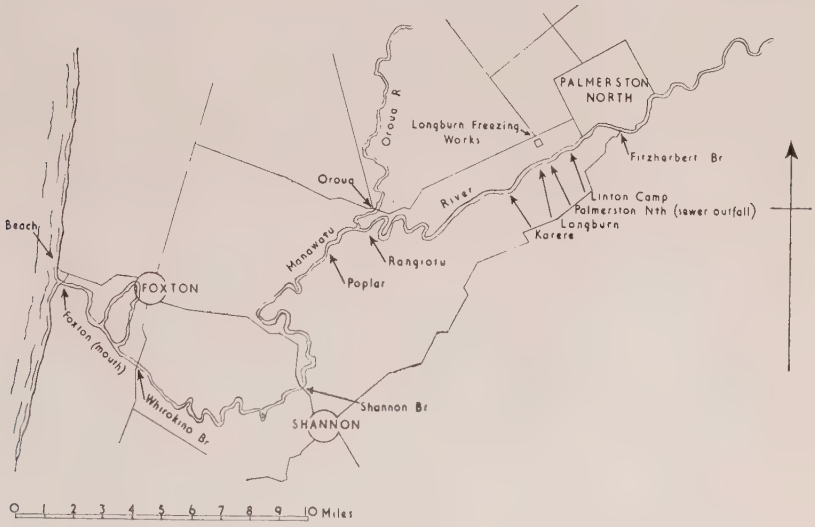

FIG. 1.—Sketch map of the area surveyed, showing stations on the Manawatu River.

The investigation was designed to provide counts of coliforms, both presumptive and confirmed, to record temperature of the water, the dissolved oxygen, biochemical oxygen demand (B.O.D.), pH value, and plankton counts. Examination of maps and a sanitary survey resulted in the selection of eight sampling stations (Fig. 1) and sampling at more or less regular intervals for the entire 24 hours. Arrangements were made to have available six motor cars and trucks, and a sampling staff of thirty, mainly from the engineering staff of the Palmerston North City Council, with seven members of the Wellington City Council Laboratory staff, and three inspecting officers of the Department of Health.

The survey was commenced on 4 February, 1957. Headquarters were established at the Laboratory of Grasslands Division, D.S.I.R., where offices and laboratory space, together with the use of cold-storage facilities were made available.

The collected samples were returned to the headquarters, where the B.O.D. and bacteriological samples were held in cold storage. The dissolved oxygen analyses were done immediately, many having been commenced at the time of sampling. On 6 March another brief survey was made, again over 24 hours, but on a restricted basis.

METHODS OF ANALYSIS

Bacteriological Examination

Coliforms were examined using lactose broth, followed by confirmation for faecal *Escherichia coli,* type 1, by incubation of sub-cultures in brilliant green lactose bile broth and in peptone water at a temperature of 44° C overnight according to the technique of McKenzie, Taylor, and Gilbert (1948).

It was thought that the ratio of sewage additions from the effluent to the volume of the water of the river at a flow of 400 cusecs would be of the order of 100 to 1, and on the assumption that the Palmerston North sewage effluent might have an *E. coli* type 1 MPN as high as 200,000,000/100 ml, a figure of the order of 2,000,000/100 ml might be expected in the river. Accordingly, it was decided to use dilutions of 5×1, $5 \times 0{\cdot}1$, $5 \times 0{\cdot}01$, $5 \times 0{\cdot}001$, $5 \times 0{\cdot}0001$ ml—i.e., 25 tubes were used for each sample.

The dilutions were prepared by pipetting 1 ml and 0·1 ml directly. One ml of the original sample was then diluted to 100 ml distilled water and the 0·01 ml was obtained by pipetting 0·1 ml of this dilution into the culture tube. A further 0·1 ml of this dilution was then diluted to 10 ml, and the remaining dilutions of the series were obtained by pipetting respectively 1 ml and 0·1 ml aliquots of this final dilution. This series of dilutions allowed for an MPN range of 20 to 2,400,000.

After incubating for 24 and 48 hours respectively, the positive fermentation tubes were subcultured to brilliant green-lactose-bile broth media and peptone water, and then incubated at $44° \pm 0{\cdot}1°$ C overnight. A positive confirmation was production of gas in the brilliant green media and indole in the peptone water as revealed by Ehrlich's reagent.

Chemical

Dissolved Oxygen. These determinations were done by the Alsterberg modification of the Winkler method, temperatures being recorded at the time of taking the sample. It was found that the dissolved oxygen could be determined after the samples had been returned to headquarters, since there was little more than an hour's delay between the time of sampling and the estimation, the sample being taken in a completely filled bottle, care being taken to avoid air bubbles.

The rate of oxygen consumption of the pollutional load has been given by Phelps (1944).

$$\text{Log } L_a/L_o = -k\,t$$

Where k = 0·1 at 20° C, and 0·125 at 24° C.
L_a = initial B.O.D.
L_o = B.O.D. after time t

From this it may be calculated that any error due to the oxidation of the B.O.D. during the hour following sampling is in the order of 2%, which is negligible in the case of the Palmerston North samples. During daylight hours, many of the D.O. tests were commenced at the site.

The titrations for the liberated iodine were performed electrometrically by the dead stop method of titration, consisting of placing two platinum electrodes in the magnetically stirred solution and applying a small potential of +0·2V from a single potentiometer. A microammeter is connected in the series with the circuit. In the presence of free iodine a current is produced which, upon titration with standard thiosulphate, declines, and the end-point is reached when a further small addition of titrant produces no further decrease of current.

Biochemical Oxygen Demand (B.O.D.)

The B.O.D.s were determined by examining the reduction in dissolved oxygen of the original sample and a one-tenth dilution of it stored for 5 days at 20° C in the dark. The residual oxygen after this time was determined by the method described above.

The bottles to be used for these B.O.D. analyses were filled with both the raw and the diluted solution as soon as possible after receipt at the field laboratory. As mentioned above, the error is less than 2% if this is done in an hour or so.

DISCUSSION

The raw sewerage of Palmerston North passes into a septic tank. The effluent is drained off into an open concrete-lined channel which leads to the Mangaone Stream about a mile upstream from the Manawatu River. The Mangaone joints the Manawatu two miles downstream from the city boundary. Table 1 shows the variation in sewage flow, and Table 2 shows typical analyses of the raw sewage and effluent.

TABLE 1.—Palmerston North Effluent, Variation in Flow, 4 to 5 June 1957.

Time	Flow (cusecs)	Time	Flow (cusecs)
Noon	7·8	Midnight	6·0
1 p.m.	8·0	1 a.m.	5·0
2 p.m.	8·2	2 a.m.	5·1
3 p.m.	7·8	3 a.m.	4·3
4 p.m.	7·8	4 a.m.	3·9
5 p.m.	7·7	5 a.m.	3·7
6 p.m.	6·3	6 a.m.	3·7
7 p.m.	6·0	7 a.m.	3·7
8 p.m.	6·0	8 a.m.	4·0
9 p.m.	7·0	9 a.m.	5·6
10 p.m.	6·7	10 a.m.	7·3
11 p.m.	6·1	11 a.m.	7·5

TABLE 2.—Palmerston North Sewage Samples, 5 August 1957.

	Inlet	Outlet
pH	6·9	6·7
Free Amm. N	5·10	12·8 p.p.m.
Alb. Amm. N	0·060	2·40
Organic NH_3	15·500 p.p.m.	2·96
Nitrite N	4·08	0·040
Nitrate N	Nil	Nil
Chloride	33·2	36·9
Sulphate	24·6	20·9
Dis. Oxygen	4·4	5·6
B.O.D.	264	142
Total solids	377	327
Suspended solids	76	75
Solids in solution	301	252
Settled solids	310	288

The waste liquids from the meat works at Longburn after removal of solids by screens, save-all tanks, and sedimentation tanks, are discharged into the Manawatu a mile downstream from the point of entry of the Mangaone.

The flow of the river at Palmerston North at the time of sampling was estimated to be 750 cusecs.

The temperature of the river was found to be surprisingly high, with values up to 79° F and falling to 73° F during the night hours.

The somewhat high pH values are attributed to limestone in the headwaters of the river, there being a lime works situated near Woodville.

Bacteriological Effects

The presumptive coliform and confirmed *E. coli* type 1 figures obtained at any one station did not show any regular pattern of rise and fall. Even at the outfall of Palmerston North there were considerable variations in results which could not be correlated with sewage peaks (Fig. 2),* and were possibly eddy effects due to close proximity of the sampling point to the outfall. The difference of results between stations was, however, significant. The results for each station were averaged by taking the logarithmic mean which is given by

$$\text{MPN} = \text{antilog}\ (\Sigma \log \text{MPN}/n)$$

where n is the number of samples taken. This method of averaging has been discussed by the author (Johannesson, 1955), and this expression is the geometric mean.

*Data collected during two consecutive days are represented in the figures according to standard engineering practice as a one-day period.

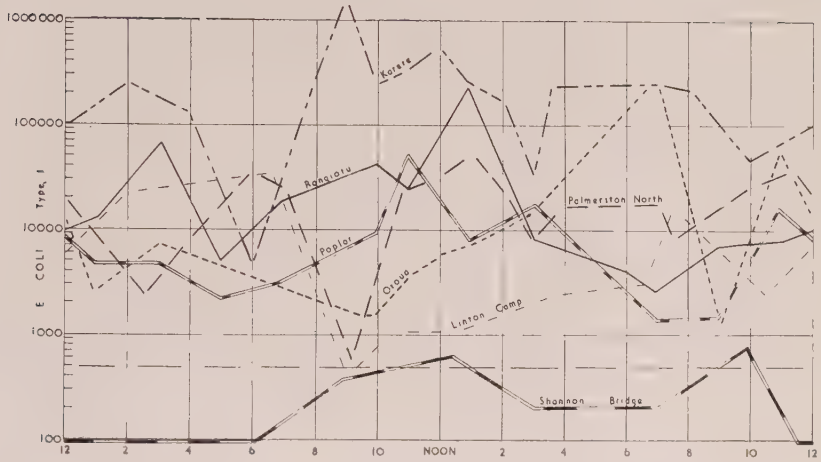

FIG. 2.—*Escherichia coli* M.P.N. for each sampling station, showing variation over 24 hours. (Samples taken from 4 p.m. on 4 February to 4 p.m. on 5 February 1957.)

Figure 3 was obtained by plotting these averaged figures logarithmetically against each station shown as distance downstream. This graph showed clearly the effect of the various polluting agencies on the river and that the capacity for self-purification in the river was very considerable.

It will be seen that there was a big increase in MPN on entry of the Palmerston North effluent, then a decrease showing a nearly linear relationship between the logarithm of the *E. coli* type 1 MPN and distance down river. The sharp increase in the MPN count at Foxton was obviously due to the sewage discharge from Foxton township.

The overall degree of purification in the river was remarkably high, and the degree of pollution in the lower reaches was very much less than had been anticipated. It was apparent that the flow rate of the river in terms of the time taken for any specific volume of water to pass from Palmerston North to the coast was very much longer than had been expected and of the order of the days.

The death rate of coliforms in the Ohio River has been quoted by Phelps (1944), and Fig. 4 shows the curves plotted against a similar curve for the Manawatu River.

The time scale for the Manawatu was derived from calculations made on the B.O.D. and the dissolved oxygen figures.

It will be noted that Fig. 3 shows an elapsed time and a probable flow totalling 110 hours, based on measurement of surface velocities. Calculations of the time constants from dissolved oxygen data by the methods of Fair (1939) and other workers, however, indicate that the effluent travel time to Shannon is of the order of ten days, which is approximately five times slower than the surface flow, and is probably due to ponding effects.

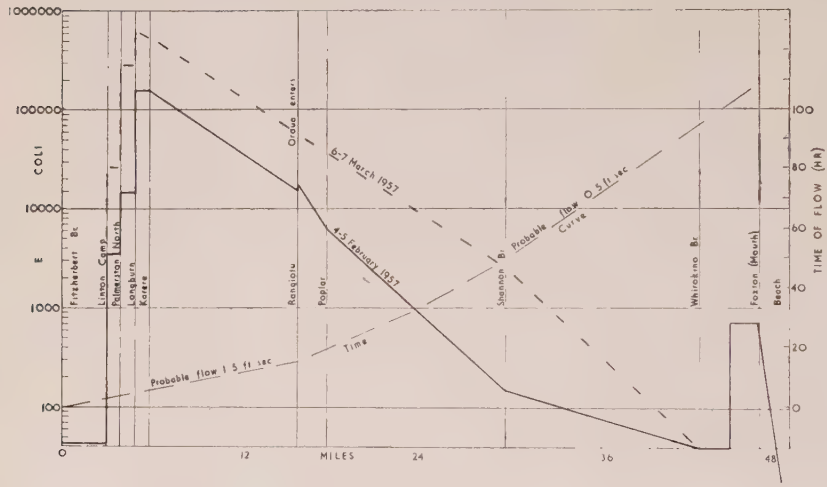

FIG. 3.—Average M.P.N. *E. coli* for each sampling station plotted against distance for both 4–5 February and 6–7 March 1957. The scale on the right-hand side gives the time from Palmerston North based on surface flow rate (broken-line curve).

It seems likely that the purification processes include (a) flocculation and precipitation of suspended solids and bacteria to the bed of the river where they undergo benthic decomposition, (b) processes of natural death in an environment unsuited to bacterial survival and multiplication, and (c) the possibility of purification due to antibiotic effects by the high plankton population of the river. This effect would be similar to that observed in oxidation of sewage oxidation ponds where, in the presence of chlorella, it is claimed that an antibiotic substance, chlorellin, is produced (Pratt, 1944; Spoehr *et al.*, 1949). Undoubtedly the destruction of coliforms in oxidation ponds is extremely efficient. It would seem that the river is actually acting as a large-scale oxidation pond. There is also the possibility of removal by direct ingestion by motile members of the protozoa group as is known to be the action of these organisms on trickling filters and on activated sludge.

The death rate of bacteria in an unfavourable environment has been shown by Chick (1910) to take place according to the law

$$\mathrm{Log}_e\ N/N_o = -k\,t$$

where N_o = initial number of bacteria present
N = number of survivors after time t.

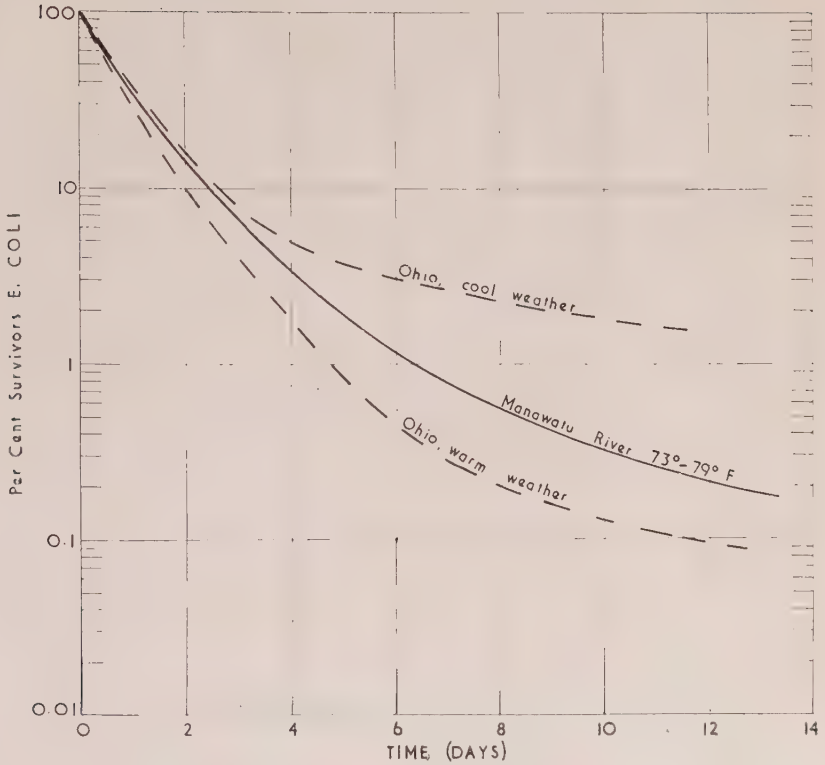

FIG. 4.—Death rate of *E. coli* in the Manawatu River compared with values for the Ohio River (from Phelps, 1944).

Figure 3 reveals a near logarithmic relation between time and numbers of organisms found.

Despite the wide range of bacterial counts found, the range of fermentation tubes taken provided in all cases a finite count, and the unfortunate use was avoided of such expressions as "24,000+" for *E. coli,* when the true count is greater than a million.

Dissolved Oxygen

When a pollutional load is introduced into a stream, the biochemical oxidation demand causes a depletion of the oxygen in the water, an effect which is accentuated by increased temperatures which accelerate the oxidation rate and retard the rate of re-aeration. The process of oxygen depletion is offset by photosynthetic oxygen production during hours of sunlight, and processes that lead to increased aeration, such as rapids or other disturbance of the water surface, together with the normal difference equilibrium between air and water. These overall

photosynthetic processes operate downstream, de-aeration of the water due to the B.O.D. predominating initially over re-aeration, until a point is reached at which the two processes are in equilibrium. From then on, the river water gains oxygen faster than it is lost, and the level of dissolved oxygen rises. This is the zone of recovery. This relationship between dissolved oxygen and time may be shown graphically, to give a typical sag curve as in Fig. 5.

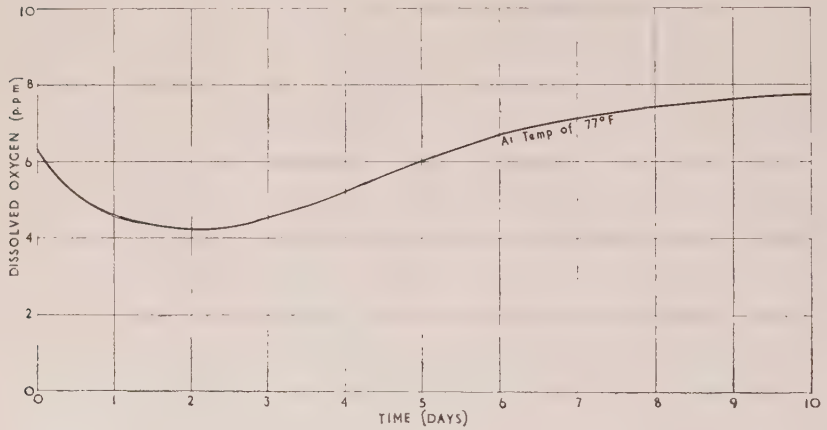

FIG. 5.—Theoretical sag curve down a river receiving a pollution load and undergoing self-purification.

The rate of oxygen consumption is increased by raised temperatures, which also act adversely against the water by decreasing the amount of oxygen and retarding the diffusion processes of re-aeration. The quantity of dissolved oxygen is also affected by barometric pressure (Henry's Law) and by salt content.

Table 3 gives the oxygen content for equilibrium with air at normal barometric pressure and various temperatures. The dissolved oxygen actually found by determination is customarily represented in terms of percentage of the theoretical value at the particular temperature and salinity of that water. Figure 6 shows the variation in percentages of oxygen for each station for the period of 24 hours. The effect of a diurnal photosynthesis was very marked, the water in the reaches near Palmerston North showing oxygen contents greater than 100% during the early afternoon. The poorest result was obtained in samples taken directly from the Oroua River, where the oxygen reached a minimum of 46% in the early hours of the morning, but in the late afternoon it had risen to 72% saturation.

TABLE 3.—Solubility of Oxygen.

Temp. ° C	Temp. ° F	Dissolved Oxygen (p.p.m.)	Temp. ° C	Temp. ° F	Dissolved Oxygen (p.p.m.)
8	46·4	11·9	19	66·2	9·4
9	48·2	11·6	20	68·0	9·2
10	50·0	11·3	21	69·8	9·0
11	51·8	11·1	22	71·6	8·8
12	53·6	10·8	23	73·4	8·7
13	55·4	10·6	24	75·2	8·5
14	57·2	10·4	25	77·0	8·4
15	59·0	10·2	26	78·8	8·2
16	60·8	10·0	27	80·6	8·1
17	62·6	9·8	28	82·4	7·9
18	64·4	9·6	29	84·2	7·8

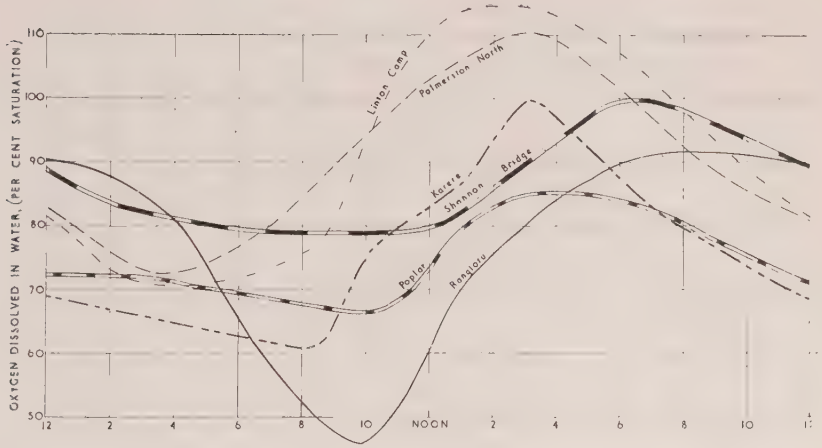

FIG. 6.—Dissolved oxygen. Variation over 24 hours for each sampling station. (Samples taken from 4 p.m. on 4 February to 4 p.m. on 5 February 1957.)

The average oxygen for each station plotted in terms of miles showed a well-defined sag curve with zones of decomposition, equilibrium, and recovery (Fig. 7). The sag commenced at the Karere station, where the average oxygen had fallen to 78%, reaching a minimum at Rangiotu, and from there on showed a recovery which was almost 100% by the time the water reached Foxton. These figures indicate that an

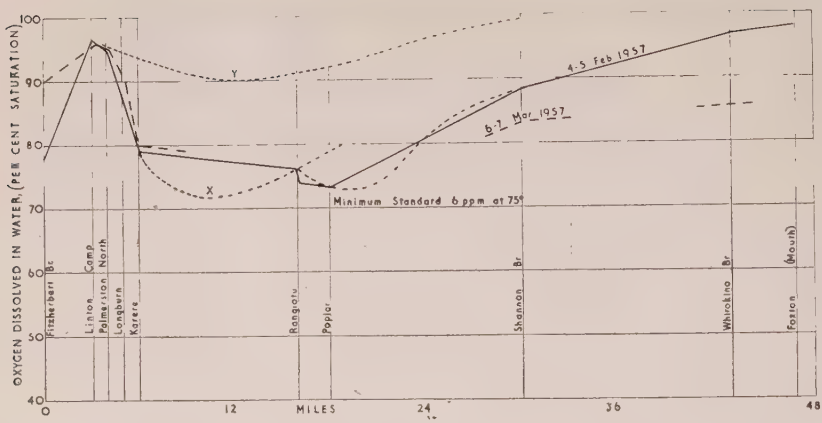

FIG. 7.—Average dissolved oxygen plotted against distance down river. The solid line is drawn by joining points plotted. The dotted line X represents the probable actual curve. The dotted line Y represents the sag curve that would have developed due to the effluent from Palmerston North alone.

almost theoretical sag-curve type of pollution and recovery was taking place. The important fact emerged that, although these samples were taken under conditions which were most disadvantageous to the stream, i.e., high temperatures and minimum flow, the minimum dissolved oxygen concentration at any time on the river proper was over a short period at Rangiotu, where the value fell to 49% saturation, but only for five hours of the day was the value below 60% saturation. This low value was caused by the increased pollution load from the Oroua Stream. By Shannon Bridge, the stream had recovered to the extent that the lowest recorded oxygen was 75% and rose to more than 100% in late afternoon.

According to Fair (1939), if the B.O.D. and oxygen deficit are known at the polluting point, then the time t_c for the minimum point of the curve is given by

$$t_c = \frac{1}{k_1(f-1)} \cdot \log\left\{ f\left[1-(f-1)\cdot\frac{D_a}{L_a} \right] \right\}$$

and the oxygen deficit D_c at this point by

$$D_c = \frac{L_a}{f} \cdot 10^{-k_1 t_c}$$

or

$$\log D_c = \log \frac{L_a}{f} - k_1 t_c$$

and for the point of inflection

$$t_i = \frac{f}{k_1(f-1)} \cdot \log f + t_c$$

and

$$\log D_i = \log\left(\frac{f+1}{f^2}\right) + \log L_a - k_1 t_i$$

L_a = initial B.O.D.
D_a = initial deficit of O_2 in p.p.m.
k_1 = 0·125 at 24° C
k_2 = taken as 0·25 for the Manawatu
f = k_2/k_1 = 2·0
t_c = critical time
D_c = oxygen deficit at time t_c
t_i = time of inflection of curve
D_i = oxygen deficit at time t_i

Calculation of the values based on the analysis at the Karere site with an initial average B.O.D. of 8·0 p.p.m. and a D.O. deficit of 1·84 p.p.m. gave the critical time as 1·9 days and a D.O. deficit of 2·6 p.p.m.

The time of inflection was found to be 4·9 days with a D.O. deficit of 2·0, which is 78% saturation at 20° C.

The curve is shown plotted as the dotted line X on Fig. 7.

Disregarding the discharge from a meat works, the corresponding figures on the river due to the sewerage of Palmerston North would be:

t_c = 2·3 days $\qquad$ t_i = 5·3 days
D_c = 0·9 p.p.m. $\qquad$ D_i = 0·67 p.p.m.

These figures provide the curve Y on Fig. 7.

Biochemical Oxygen Demand

The organic loading as revealed by the B.O.D. test was not very high, and explains why the oxygen reduction was not excessive.

Calculation of the likely B.O.D. may be made as follows:

The oxygen requirement of sewage from a predominantly residential city is widely quoted as 0·12 lb per capita per day. Thus a population of 40,000 for Palmerston North, allowing for some small industrial establishment, would have an oxygen requirement of 0·12 × 40,000 lb per day.

The industrial output of Longburn freezing water has been stated to be equivalent to a 140,000 population, which will have an oxygen requirement 140,000 × 0·12 lb. For this loading to be added to 750 cusecs of water gives a B.O.D. of

$$\frac{180{,}000 \times 0{\cdot}12}{5{\cdot}4 \times 750} \text{ p.p.m.}$$

$$= 5{\cdot}3 \text{ p.p.m.}$$

Thus the most heavily polluted sites, Karere and Oroua showed an average B.O.D. of only 7·6 and 10·2 respectively, and these values would not lead to undue oxygen depletion; the former value is in good agreement with the above calculated figure. The variation of B.O.D. during the 24-hour period for each station is shown on Fig. 8.

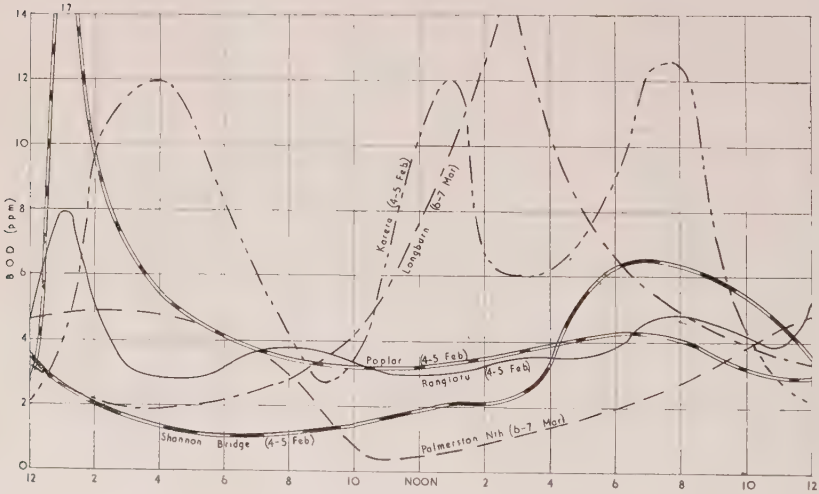

FIG. 8.—Biochemical oxygen demand (B.O.D.). Variation for each station over 24 hours.

Although the times of peak output at Palmerston North are known, the time for the effluent to pass the septic tanks and the outfall sewers is a variable factor, and the three peaks shown for the Karere samples possibly represent the morning, midday, and evening peaks, displaced only by the time lag. The peak loading from Longburn was as expected from the operation of the meat works; the peak of the Oroua was unknown.

The lowering of the B.O.D. as the water travels downstream is shown on Fig. 9.

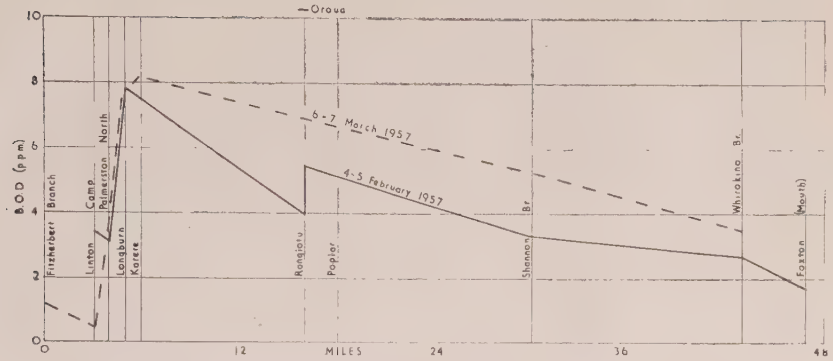

FIG. 9.—B.O.D. Average value for each station plotted against distance.

The variation in temperature and pH in the river are shown in Figs 10 and 11 respectively.

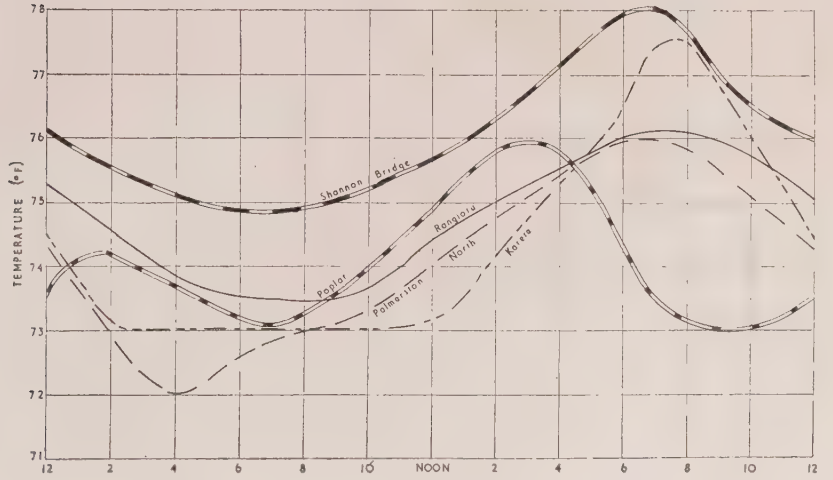

FIG. 10.—Temperature in ° F for representative stations over 24 hours (4–5 Feb.).

THE SURVEY OF 6–7 MARCH

A smaller survey carried out during 6–7 March provided confirmation of the previous survey. The data obtained confirmed very well the result of the survey of 4–5 February. Many of the results are shown on the graphs for the corresponding analyses for 4–5 February.

The 24-hour variation in *E. coli* at each station for this period is shown on Fig. 12.

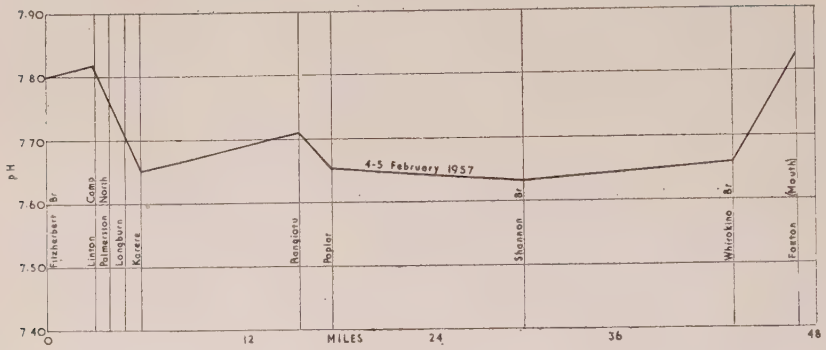

FIG. 11.—pH values along rivers. Values averaged for each station (4–5 Feb.).

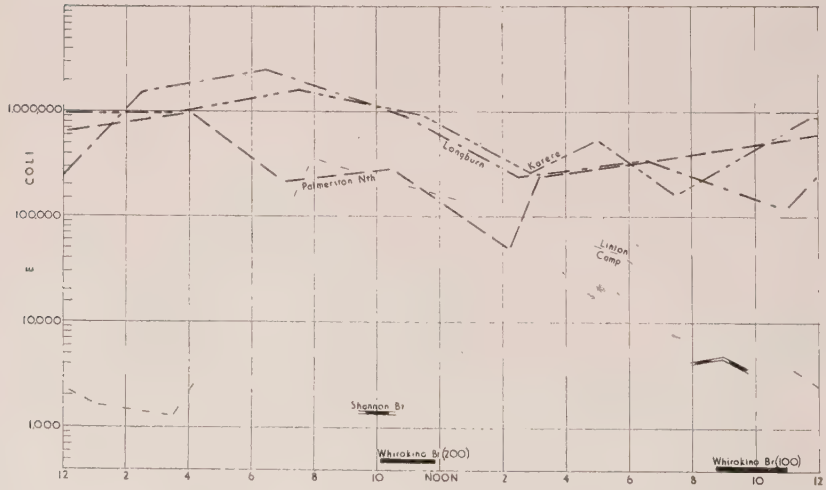

FIG. 12.—*E. coli* counts. Variations over 24 hours at each sampling point (6–7 March).

CONCLUSIONS

A bacteriological and chemical survey of the Manawatu River carried out over a 24-hour period with sampling stations between Palmerston North and the mouth of the river reveals the self-purification capacity of the river to be very high.

The presence of limestone country near Woodville raises the pH of the water to nearly 8 as it passes near Palmerston North. The low-graded beds of the tributaries allow water to become warm in mid-summer. The removal of coliform bacteria by natural processes of

purification, sedimentation action of predatory microorganisms, antibiotic effects, and natural death is very considerable, and by the time the water has reached Foxton the numbers of bacteria have reached very low levels. Foxton beach showed no contamination.

The rate of B.O.D. loading is not too great for the purifying capacity of the river, which still provides a margin of aeration. The diurnal effect of the photosynthetic processes is particularly marked, values above 100% oxygen saturation being obtained, even under the conditions of low flow and high temperature.

ACKNOWLEDGEMENTS

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The contribution made by Mr R. Annabel, of the Palmerston City Council, in arranging the field work, personnel, and transport of the surveys and for the preliminary draughting of the diagrams is gratefully acknowledged.

Some thirty people were employed in the sampling and laboratory work, being recruited from the Palmerston North City Council, the Manawatu district office of the Department of Health, and the Wellington City Council Laboratory, of whom seven were employed on the field work.

Thanks are also expressed to Dr A. T. Johns, of the Plant Chemistry Laboratory, D.S.I.R., for laboratory space and the use of the cafeteria

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THE OCCURRENCE OF AN ARGASID TICK IN NEW ZEALAND

By L. J. Dumbleton, Entomology Division, Department of Scientific and Industrial Research

(Received for publication, 3 October 1958)

Summary

The occurrence in New Zealand of *Ornithodoros capensis* Neumann is recorded. Descriptions of the adult and immature stages are given together with remarks on the status of *O. sancti-pauli* Schulze and the relationship of both species to *O. talaje* (Guérin Menéville).

Introduction

Few Argasid ticks are recorded in the regions adjoining New Zealand. Australia has two species of *Argas*, the native *A. lagenoplastis* Froggatt on birds, and the cosmopolitan fowl tick, *A. persicus* (Oken) which is a vector of avian spirochaetosis there. The genus *Ornithodoros* is poorly represented in Asia but has species on bats in Malaya (*O. batuensis* Hirst) in Java and Timor (*O. steini* Schulze) and an undescribed species in the Solomon Islands. In Australia *Ornithodoros* is represented by *O. gurneyi* Warburton on kangaroos and *O. capensis* Neumann on penguins.

It was stated in a previous paper (Dumbleton, 1953) that ticks of the family Argasidae were not present in New Zealand but in 1957 Mr J. R. Jackson submitted to the author a tick which was present in large numbers in nests and under stones in a Spotted Shag (*Stictocarbo punctatus punctatus*) colony at Perpendicular Point, near Punakaiki, on the West Coast of the South Island. Further specimens were secured later by Mr Jackson from nests of the same bird on Banks Peninsula near Birdlings Flat.

The specimens proved to be Argasid ticks belonging to the genus *Ornithodoros*. Three species of the genus are known to attack sea birds; *O. capensis* Neumann, *O. sancti-pauli* Schulze and *O. amblus* Chamberlin. The New Zealand specimens proved to be *O. capensis*. They were compared with specimens from Dassen Island, South Africa which were kindly supplied by Dr Gertrud Theiler of Onderstepoort, with other South African specimens loaned by the British Museum,

and with specimens of *O. talaje* from near the type locality in Guatemala which were determined and sent to the author by Dr G. M. Kohls of the Rocky Mountain Laboratory. Species of *Ornithodoros* are distributed as far as 45° N in Europe (*O. coniceps* in Northern Italy), and 50° N in North America (*O. parkeri* in Canada). The present record of *capensis* is the southernmost for the genus, 42° S. The species is not so far reported from any point in South America or the Falkland Islands nor from any of the following islands all of which lie south of 47° S: Crozets, Herd, Campbell, Kerguelen, Auckland, and McQuarrie. The distribution of *O. capensis*, hitherto known from islands off Cape Colony, Tristan da Cunha, St. Pauls Rocks, and Ascension in the Atlantic, from the southern coast of Australia and from Guam, has been greatly extended by the paper of Kohls (1957) which records it from the Revillagigedo Archipelago off the Pacific coast of Mexico, Galapagos Islands, Hawaiian Islands, and Japan.

The earlier host records of *capensis* were from penguins and it appeared possible that records from other sea birds from localities nearer the equator might refer to the smaller form described as *sancti-pauli* Schulze. The present record as well as many of those of Kohls makes it apparent that the species is not restricted to penguins. Bedford (1934) reports that *capensis* readily attacks both and and fowls. In most cases it would have little chance of doing this since the ticks occur in the nest material and under rocks in the nesting bird colony. In feeding they engorge quickly and leave the host again in a manner similar to the bedbug. This habit probably explains why they have not previously been reported from New Zealand. Other species of *Ornithodoros* transmit the spirochaete of relapsing fever in the United States and in Africa.

The following key and description will enable the identification of this tick and complete the keys given in the previous paper.

Super-Family IXODOIDEA

Scutum covering all (males) or part (females) of the dorsum in all stages; capitulum anterior, visible dorsally.....FAMILY IXODIDAE.

Scutum absent in all stages; capitulum ventral and not visible dorsally in adults and nymphs, but visible dorsally in larvae

.....FAMILY ARGASIDAE.

Ornithodoros is the only Argasid genus represented in New Zealand. It may be distinguished from *Argas* by the absence of the marginal sutural line differing in sculpture from the dorsal and ventral surfaces which it separates in *Argas*.

Genus Ornithodoros Koch 1844

Ornithodoros capensis Neumann 1901

This tick has been described by Nuttall *et al.* (1907, pp. 61-62, Pl. 3); Bedford (1934, p. 74, figs 23-26-; and Kohls (1957, pp. 88-90), fig. 1).

Female: (Fig. 1 (a-g)). Length 4·5 to 6·0 mm, width 2·5 to 4 mm. Elongate pear-shaped, conical anteriorly, rounded posteriorly, widest posteriorly; margin slightly concave between anterior point and a prominence opposite coxa I also between this latter and another prominence opposite coxa II sides posterad of this sub-parallel but constricted slightly immediately behind coxa IV. Colour dark reddish-brown, legs paler yellowish-brown. Dorsal (Fig. 1 (a)) and ventral (Fig. 1 (b)) surfaces (except for the regularly arranged discs) closely covered with mammillae (Fig. 1 (c)) some of which bear a single very short seta. Mammillae larger and more rounded on the posterior and postero-lateral dorsal margins. Legs, basis capituli, and first palpal joint micromammillated. Coxae I and II also bear modified mammilliae or tubercles. Coxae I and II separated, others contiguous. Legs with tarsus I (Fig. 1 (d)) 0·65 mm long, slight sub-apical dorsal prominence; Haller's organ (Fig. 1 (e)) with transverse capsule; posterior hair tuft with 4 setae; anterior pit or trough with 6 conical setae or sense cones; two distal setae subequal in length. Hood small, sometimes separated by a notch from the anterior median point of dorsum, distinctly separated from cheeks. Cheeks sub-rectangular, higher anteriorly. Camerostome enclosed by hood and cheeks, floor between cheeks with 30 to 40 setae. Capitulum (Fig. 1 (f)) with basis 0·3 mm long and 0·6 mm wide, transverse with one post-palpal seta anteriorly on each side and 3 or 4 postero-lateral setae on each side. Palpi: first joint with knife-like edge mesally, third and fourth joints commonly curved ventrad. Hypostome (Fig. 1 (g)) short, broad, notched apically, dentition 2/2 with 4 or 5 small rounded teeth on each side. Post- hypostomal hair about two-thirds length of hypostome. Coxal folds separating coxae I and II. Supra-coxal fold present. Dorso-ventral groove absent. Pre-anal, transverse post-anal, and median post-anal grooves present. The anterior and posterior margins of the transverse post-anal groove smooth, without mammillation. Genital orifice slightly posterior to coxae I, frame diamond-shaped with transverse diagonal line. Eyes absent. Anus posterior to coxae IV at two-thirds length, frame circular enclosing two semi-circular lobes each with a single seta.

Male: Similar to female except in smaller size, 3·5 to 4·5 mm long, 2 to 3 mm wide, and the broad inverted U-shape of the genital office.

Nymphs Similar to female except that the genital orifice is absent. Length 1·5 to 4·5 mm long.

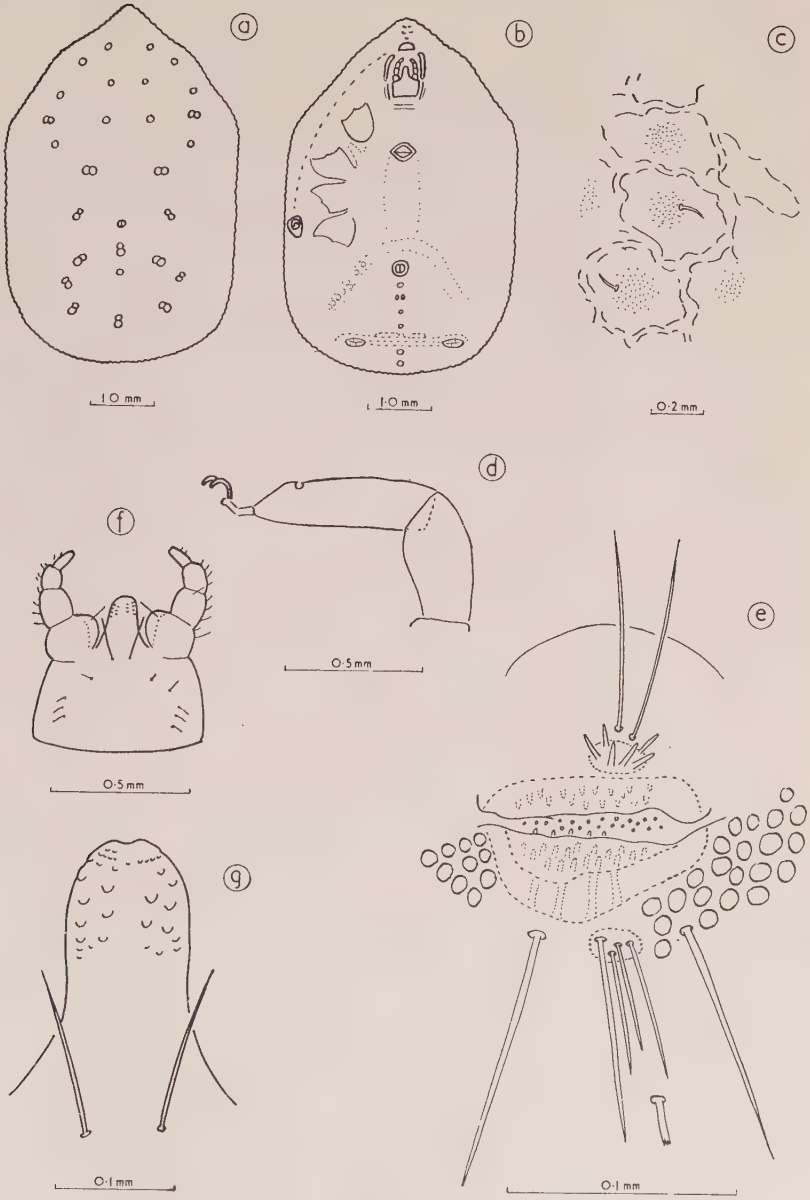

FIG. 1.—(a) *O. capensis,* female, dorsal (scale in mm).
(b) *O. capensis,* female, ventral.
(c) *O. capensis,* female, mammillae.
(d) *O. capensis,* female, tarsus I, lateral.
(e) *O. capensis,* female, Haller's organ, lateral.
(f) *O. capensis,* female, capitulum, ventral.
(g) *O. capensis,* female, hypostome, ventral.

Larva: (Fig. 2 (a-d)). Length unengorged 0·5 mm, engorged 1·5 mm long, 1·0 mm wide. Shape sub-circular when unengorged, more elongate when engorged. Capitulum terminal when unengorged, more ventral when engorged. Palpal joints elongate—twice as long as wide. Hypostome (Fig. 2 (a)) dentition 4/4 anteriorly, 2/2 posteriorly, 13 teeth in outer file. Tarsus I (Fig. 2 (b)) length 0·28 mm setation as in the figure. Haller's organ with sub-circular capsule containing 4 sense hairs, posterior hair tuft with 3 setae one longer than others, distal pit or trough with 6 sense cones. A single long median seta distally. Dorsal setation (Fig. 2 (c)) 17-18 setae on each side. Ventral setation (Fig. 2 (d)). Post-hypostomal seta shorter than post-palpal seta, other setae 14 on each side plus one median post-anal and one on each anal lobe.

Eggs: Spherical, pale, 0·4 mm diameter.

N.Z. Distribution: Perpendicular Point, West Coast, September 1957. Banks Peninsula near Birdlings Flat.

Host: Spotted Shag (*Stictocarbo punctatus punctatus*)

Collector: J. R. Jackson.

Specimens in the author's collection and in Canterbury Museum. The type is presumed to be in the Neumann collection, Toulouse. *O. capensis* belongs to the group of *Ornithodoros* in which cheeks enclosing the capitulum are present and dorsal humps on the tarsi absent. Its nearest relative appears to be *O. talaje* Guérin Menéville of which it was first described as a subspecies. *O. talaje* is, however, distinct morphologically and in hosts and distribution.

The three sea-bird infesting species may be identified from the following key in which the characters of *O. amblus* are taken from Cooley and Kohls (1944).

1. Legs not micromammillated; tarsus I without sub-apical prominence; Haller's organ at about two-thirds length	*amblus* Chamberlin (Penguin-Chincha Is., Peru)
Not as above	(2)
2. More bluntly rounded anteriorly; mammillae conical with radial ridges; hood separated by notch from anterior dorsum, in contact with the large oval cheeks; Haller's organ with sub-circular capsule at about four-fifths length	*talaje* Guérin Menéville (land mammals—N. and S. America)

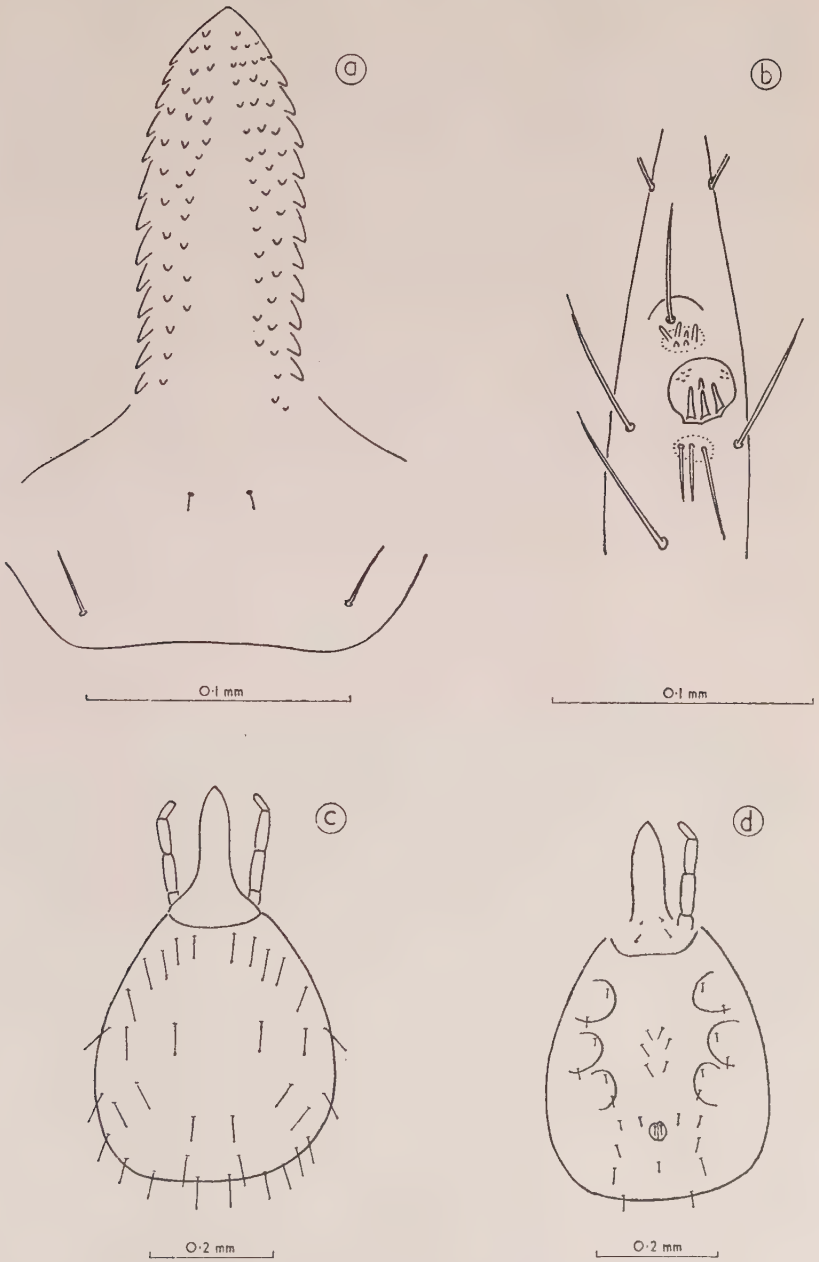

FIG. 2.—(a) *O. capensis,* larva, hypostome, ventral.
(b) *O. capensis,* larva, tarsus I, dorsal.
(c) *O. capensis,* larva, dorsal chaetotaxy.
(d) *O. capensis,* larva, ventral chaetotaxy.

Distinctly conical anteriorly; mammillae rounded without radial ridges; no distinct notch between hood and dorsum, hood distinctly separated from smaller sub-rectangular cheeks; Haller's organ with transverse capsule at about seven-tenths length	*capensis* Neumann (Penguins, etc.—N. Pacific, Indian and South Atlantic oceans and Tasman Sea.)

Schulze (1941, p. 544) gave sub-specific status, as *Alectorobius talaje sancti-pauli*, to a small (4 mm long) lighter coloured form of which he examined five females from the nests of *Anous stolidus* from St. Paul Rocks. The origin of the specimens was not indicated. The genus *Alectorobius* Pocock 1907 was erected with *talaje* as genotype and is recognized by Schulze (1941) but not by Nuttall *et al.* (1908), Zumpt (1952) or by Cooley and Kohls (1944). Through the

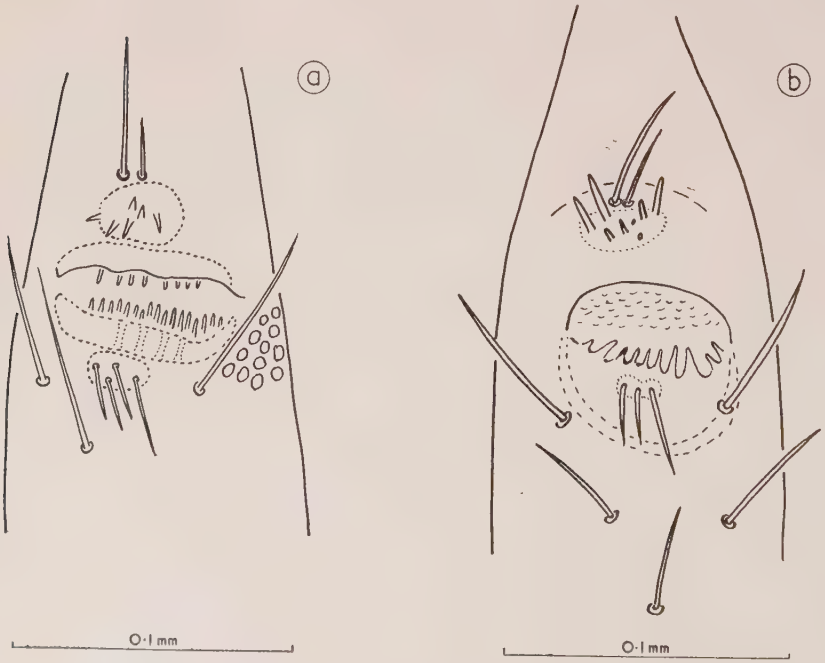

FIG. 3.—(a) *O. sancti-pauli*, female, Haller's organ, dorsal. (b) *O. talaje*, female, Haller's organ, dorsal.

kindness of the British Museum the author has been able to examine three females and three males of a small yellowish form collected by the Challenger Expedition from birds nests on St. Paul Rocks, 28 August 1873. In two specimens which were examined Haller's organ (Fig. 3 (a)) was found to be similar to that of *capensis*—a transverse capsule—with no definable difference of specific value. The only difference noted was in the two median setae distad of the trough which are subequal in *capensis* whereas in *sancti-pauli* one is half the length of the other.

Any distinction between *capensis* and *sancti-pauli* rests at present only on size and colour. Kohls (1957) regards *sancti-pauli* as of doubtful validity. I would agree that it does not merit specific rank and is only doubtfully worth rank as a subspecies of *capensis*.

There are puzzling inconsistencies in the text of Schulze (1941). On p. 542 he states that the capsule of *talaje* is subcircular while that of *capensis* is transverse as also is that of *sancti-pauli*, yet on p. 544 he states that *sancti-pauli* is similar in capsule to *talaje* and that *sancti-pauli* is a small *capensis* with the capsule of *talaje*. There are also inconsistencies between text and figures which suggest confusion of specimens or transposition of the figures appearing over the titles to figures 70 and 71.

Figure 70 shows a sub-circular capsule purporting to be that of *capensis* while figures 71 and 72 show transverse capsules purporting to be those of *talaje* and *sancti-pauli* respectively.

The capsule of Haller's organ in *O. talaje* (Fig. 3 (b)) is subquadrate or sub-circular. The two medio-dorsal distal setae are unequal as Schulze states. In the single female tarsus which the present author has for examination there are only three setae in the posterior hair tuft but there are four in both tarsi of the male. The proximal lip of the orifice appears to be toothed and the capsule is invaginated beneath the posterior hair tuft.

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ALATE APHIDS TRAPPED IN AUCKLAND, NEW ZEALAND USING MOERICKE COLOUR TRAPS

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Summary

Eight traps with two types of yellow paint were exposed for twelve months at crop height. Traps were cleared every two or three days and the aphids counted and identified. During the year, 4,272 aphids belonging to 24 genera and 39 species were collected. The most abundant species were *Lipaphis erysimi* (Kltb.), *Myzus persicae* (Sulz.), *Brevicoryne brassicae* (L.), *Hydaphis foeniculi* (Pass.), and *Myzus ornatus* Laing, which together constituted 83% of the total individuals trapped.

Zinc chromate painted traps were generally more efficient than those painted with Colonex bright yellow, but different species differed in their relative acceptance of the two paints. *M. persicae, M. ornatus, B. brassicae,* and *Macrosiphum rosae* showed a strong "preference" for zinc chromate, *L. erysimi* showed a weaker preference for zinc chromate, while *H. foeniculi* were found in equal numbers in both paints. Discrimination between the two paints was attributed to differential response of various species to yellow and blue-violet regions of the spectrum.

Total weekly catches were strongly correlated with mean air temperature ($r = 0{\cdot}77$), but not with other climatic factors tested.

Introduction

Movement and dispersion of aphids occur primarily through the flight of winged forms. The timing and intensity of aphid flights in the field is of considerable interest for epidemiological reasons, since many species not only damage plants through their feeding activities but are also responsible for transmission of a number of plant virus diseases. Studies on the cabbage aphid (*Brevicoryne brassicae* (L.))—a serious pest of Brassica crops wherever they are grown in this country—indicated the need for more information on the movement of alate adult aphids. This investigation was therefore undertaken on a limited scale in one area to examine the suitability of the method for wider-scale field application.

In other countries, various types of aphid traps have been used—e.g., sticky traps, suction traps, or colour traps. Coloured traps of the type developed by Moericke (1954) were used here because of their cheapness and simplicity. These are simply shallow trays, painted yellow inside, and containing a little water. The use and effectiveness of these traps have been discussed in detail by Moericke (1953, 1954a, 1955a). Comparative results from coloured, sticky, and suction traps have also been reported by Moericke (1955b), Eastop (1955, 1957), and Heathcote (1957).

This paper deals with the results of twelve months' trapping with yellow Moericke traps at crop height, at the Plant Diseases Division, Auckland from July 1956 to July 1957.

MATERIAL AND METHODS

The traps used were eight galvanized iron glasshouse trays (63·5 × 49 × 5 cm), painted on the outside with dark green paint. Four were painted inside with several coats of zinc chromate priming paint, while the other four were painted inside with several coats of bright yellow "Colonex" (a chlorinated rubber paint).

In the field, the traps were half-filled with water and placed 30 cm above the ground on boxes approximately 6 ft apart (Fig. 1). The traps were in two rows with the two types of paint alternating.

FIG. 1.—Colour traps in position in Brassica trial. Alates are being removed from one trap with the aid of a fine paintbrush.

Preliminary experiments using 0·01% parathion solution + wetting agent as the trapping fluid showed that there was no advantage in including an insecticide, as no more aphids were caught in this mixture than in tap water. On the other hand, numerous flies, moths, and beetles were caught in the insecticide, and these made clearing the traps more difficult. During the survey, tap water alone was used, and this was renewed several times a week, depending upon weather conditions.

The traps were cleared every two or three days and the alate aphids found were preserved in alcohol for subsequent identification. Separate records were kept of catches from each trap.

At the start of the period, the trap area was covered with low grass and mixed weeds, but at the end of December 1956 a Brassica varietal trial was laid down in the vicinity of the traps. These plants were present until May 1957. (This period in indicated by arrows in Fig. 2.) The traps were located in the centre of an experimental area of several acres where a wide variety of crops was present from time to time throughout the sampling period.

RESULTS

General

Weekly totals from all traps for each species caught are summarized in Table 1. Nomenclature follows that of Cottier (1953) and species are arranged in Table 1 in the same order as in that monograph.

Of the total of 4,272 aphids trapped, 83% belonged to five species—viz., *Lipaphis erysimi* (Kltb.), *Myzus persicae* (Sulz.), *Brevicoryne brassicae* (L.), *Hydaphis foeniculi* (Pass.), or *Myzus ornatus* Laing. The total weekly catch and the weekly catch of each species is shown graphically in Fig. 2. *L. erysimi, M. persicae,* and *B. brassicae* were breeding in the adjacent Brassica trial. *M. ornatus* is known to be abundant in this area on a variety of hosts. However, the reason for the abundance of *H. foeniculi* is obscure.

The 39 species of aphids trapped represent more than two-thirds of the total number of alate species hitherto recorded in this country (Cottier, 1953)—rather a surprising result from such a limited area (27 sq. ft). In addition, at least two species were encountered which had not previously been recorded in New Zealand—viz., *Myzus ascalonicus* Doncaster, which has been described elsewhere as a pest of onions and a virus vector (Doncaster, 1946), and *Rhopalosiphoninus latysiphon* Davidson. This appears to be the first record of the collection of alate adults of *Geoica lucifuga* (Z.) and *Aploneura lentisci* (Pass.) in this country.

Sexuales were trapped only in the months of May, July, August, September, and October. One was a male *B. brassicae* caught in May 1957. This record is of some interest since this species apparently reproduces only parthenogenetically in New Zealand. Other males trapped were *Brachycaudus helichrysi* (October), *Capitophorus eleagni* (September), *Hyperomyzus carduellinus* (September), *Myzus persicae* (July), and two unidentified specimens.

Effects of Weather on Trapping

The total catch of aphids varied seasonally, more being caught in summer than in winter. However, the results also revealed smaller trends within seasons and greater variation between some adjacent weekly means than could be attributed to sampling error. To investigate

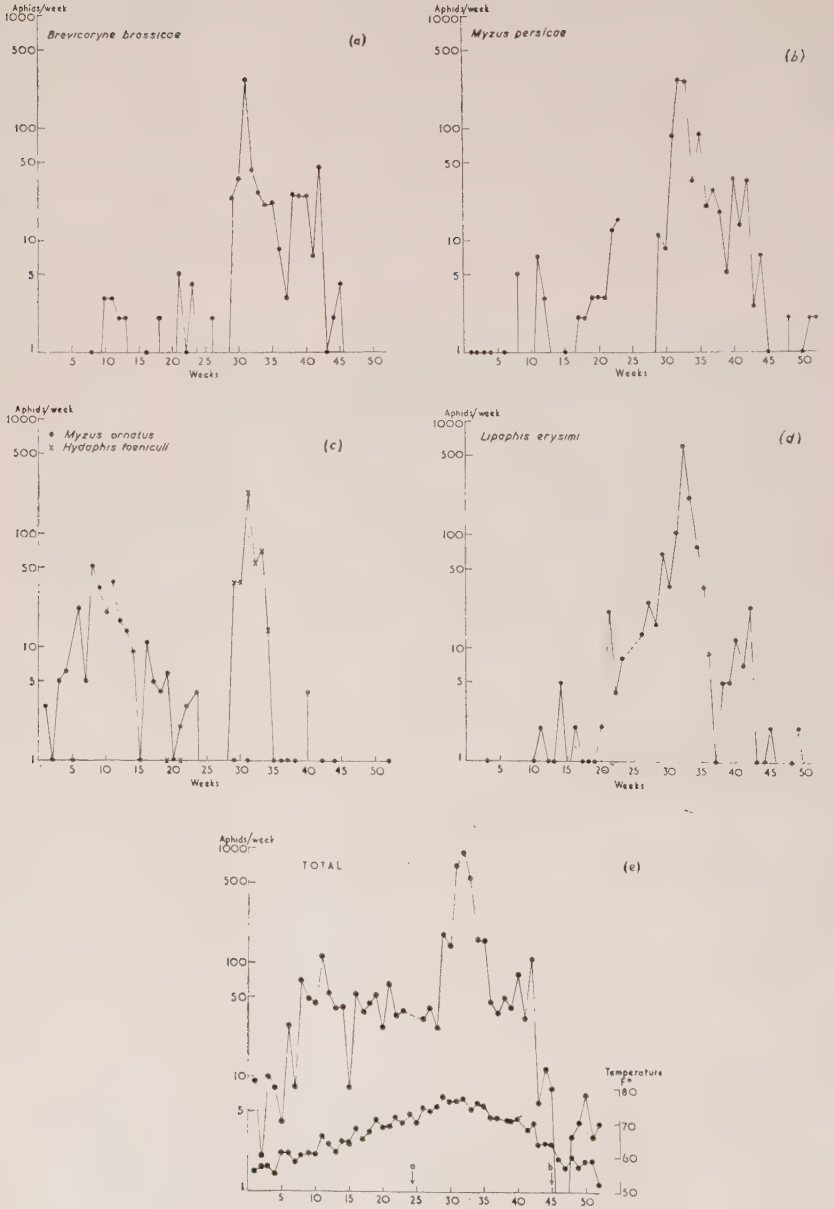

FIG. 2.—Total aphid catch per week and mean weekly maximum temperature (e), and weekly catches of most abundant species: (a) *Brevicoryne brassicae*; (b) *Myzus persicae* (c) *Myzus ornatus* and *Hydaphis foeniculi*; (d) *Lipaphis erysimi*.

… Weekly Catch …

Species	Week No. 1 (1956 July)	2	3	4 (August)	5	6	7	8 (September)	9	10	11	12 (October)	13	14	Weeks 15 onward and Total
… Baker			1												[illegible]
… (Klth.)										1	2	1			[illegible]
… (Klth.)											1		1		[illegible]
… tetrarhodus (Walk.)														1	[illegible]
… (Klth.)												[illegible]			[illegible]
… (Scop.)															[illegible]
… (L.)	1											1	2		[illegible]
… (Theob.)															[illegible]
… …ndis (Fitch)															[illegible]
… …ntii (B.d.F.)															[illegible]
… (B.d.F.)															[illegible]
… (K…)															[illegible]
… (Teth.)											[illegible]				[illegible]
…															[illegible]
…															[illegible]
… …anborni (Gill.)															[illegible]
… euphorbiae (Thom.)			1					1			2	2	1		[illegible]
… (L.)										2	12	1	2		[illegible]
… (Fab.)											1				[illegible]
… …ni (Del G.)	1								2		1 2		1		[illegible]
… …ulae ((Theo.)															[illegible]
… (Buck.)							1			3	2	1			[illegible]
… (Klth.)	1				1	1		1	[illegible]		4		6		[illegible]
… (Koch)															[illegible]
… (Dav.)													1		[illegible]
… (The…)	1				1				1	1	2 3	1	1		[illegible]
… (Pers.)							1	1			2	1	1		[illegible]
… (Walk.)															[illegible]
… (F.)	1				1		1		1	3	25		2		[illegible]
… Laing	3	1	5	6	1	22	5	51		20	38	17	4		[illegible]
… (Sulz.)		1	1	1		1		5			7				[illegible]
… Don.						1		4		10	4	1			[illegible]
… (Pass.)															[illegible]
… (L.)								1		3	3				[illegible]
… (Klth.)			1							1	2	1			[illegible]
… (Pass.)															[illegible]
… (Zeh.)															[illegible]
… (Pass.)															[illegible]
… …terum (Haus.)															[illegible]
Unidentified	1		1	18		1			1		1		1		[illegible]
Total … per week	9	2	10	8	4	28	8	71	[illegible]	44	115	54	[illegible]	41	[illegible]

the influence of weather on these major and minor trends, the effect of several climatic factors on total weekly catch was tested by the method of multiple correlation.

Of the factors tested (screen temperature, inches of rainfall, number of rain days, hours of bright sunshine, wind, day-length), only temperature proved to be strongly correlated with weekly catches. The correlation cofficient r for mean weekly maximum temperature was 0·77 and for weekly mean temperature it was 0·68. (The difference between these coefficients was not significant.) Thus, some 60% of the variation in weekly catches could be accounted for by temperature alone.

Significant, but lower, correlations were also obtained with rainfall and sunshine. When these were considered in conjunction with temperature, however, the improvement in correlation was not significant. It is therefore unlikely that weekly catches were substantially affected by these factors.

The use of weekly means has a smoothing effect on the variables under consideration, and no doubt considerably more could be learnt of the effect of climatic factors if daily aphid catches and microclimatic observations could be used. However, aphid numbers were too small to permit the use of smaller units than weekly totals.

From the studies of Johnson (1954) and others, it is known that the number of aphids flying fluctuates from hour to hour as well as from day to day. Thus considerably closer analysis would be required to separate the effects of various climatic factors on aphid movement. Nevertheless, it is of some interest that the overall weekly catch of aphids was so strongly correlated with air temperature.

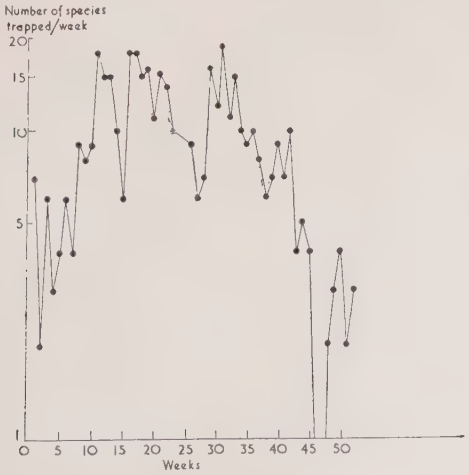

FIG. 3.—Seasonal variation in species abundance.

There was a high correlation ($r = 0{\cdot}82$) between the number of species trapped per week (Fig. 3) and the number of individuals trapped (both expressed as logarithms). This correlation improved when peak counts were omitted. Thus, excluding the three highest counts (>200 individuals per week), $r = 0{\cdot}84$, and excluding the nine counts of over 100 individuals per week, $r = 0{\cdot}87$.

Peaks of species abundance occurred in late September, early November, and mid-February. A smaller peak was observed in April. Total aphid catches were at a high level from early September to the beginning of May. There were two main peaks of abundance: the first at the end of September (week 11) and a second larger one in mid-February (weeks 31 and 32). A smaller peak occurred at the end of April (week 42). In only two weeks of the year were no aphids trapped.

Myzus ornatus was most abundant in spring, while *Hydaphis foeniculi* had a steep peak of abundance in midsummer. The Brassica aphids *B. brassicae, M. persicae,* and *L. erysimi* had two main peaks of abundance: a large one in midsummer corresponding to maximum populations on the plants and a smaller one in autumn (about the end of April) resulting from alate production in response to deficiency of food through the withering and death of leaves of their hosts.

The important virus vector, *Myzus persicae,* was trapped in 36 weeks of the year, as was also *Lipaphis erysimi. Brevicoryne brassicae* and *Myzus ornatus* were trapped in the course of 28 and 33 weeks respectively. On the other hand, *Hydaphis foeniculi,* though the fourth most abundant species, was trapped in only eight weeks.

The efficiency of these traps, in terms of the proportion of the theoretical flying population sampled, is considered separately by Dr H. R. Thompson (1958).

Effect of Type of Paint

In general, more aphids were trapped in trays painted with zinc chromate than in those painted with Colonex. Statistical analysis of catches of the most abundant species revealed, however, that different species behaved differently towards the two paints.

Species with catches of more than 50 individuals were first considered separately and the total catches analysed for differences between paints, using the log $(n + 1)$ transformation. Weekly catches per trap were then considered in more detail for *M. ornatus* (weeks 9 to 13) and for *B. brassicae, M. persicae, L. erysimi,* and *H. foeniculi* (weeks 29 to 33). The results of these analyses are summarized in Tables 2 and 3.

In the analyses of single species, differences between paints were significant at the 5% level for *M. ornatus* and *M. persicae* and at the 10% level for *B. brassicae.* In the combined analysis, differences between

TABLE 2.—Combined Analysis of Variance for Catches of *M. persicae*, *B. brassicae*, *L. erysimi*, and *H. foeniculi* over Weeks 29 to 33.

	S.S.	d.f.	M.S.	F.
Main Plots				
Between blocks (B)	0·1063	3	0·0354	
Between paints (P)	2·0408	1	2·0408	5·06
B.P. interaction	1·2095	3	0·4032	
	3·3566	7		
Sub-plots				
Between weeks (W)	13·1707	4	3·2927	18·31+++
WP interaction	0·3514	4	0·0879	
Error (a)	4·3154	24	0·1798	
	17·8375	39		
Sub-sub-plots				
Between species (S)	2·8435	3	0·9478	175·55+++
SW interaction	0·8029	3	0·2676	49·56+++
SW interaction	11·3205	12	0·9434	174·70+++
Error (b)	0·5557	102	0·0054	
Total	36·7167	159		

(+++Significant at 0·1% level)

Species	Mean catch per trap: species versus paints (as log $(n + 1)$)	
	Zinc chromate	Colonex
M. persicae	1·04	0·67
L. erysimi	1·24	1·07
B. brassicae	0·97	0·63
H. foeniculi	0·95	0·93

TABLE 3.—Relative Catch of Aphids in Zinc Chromate versus Colonex Painted Traps.

Species	Ratio of geometric means Zinc chromate/Colonex	Difference between means of log $(n + 1)$ per trap
Myzus ornatus	3·0	0·48+
Macrosiphum rosae	2·6	0·41+
Myzus persicae	2·3	0·37+
Brevicoryne brassicae	2·2	0·34
Aphis citricidus	2·1	0·32
Brachycaudus helichrysi	2·1	0·31
Capitophorus elaeagni	1·7	0·24
Lipaphis erysimi	1·5	0·17
Hyperomyzus carduellinus	1·2	0·07
Hydaphis foeniculi	1·1	0·02

(+Difference between paints significant at 5% level)

species and weeks were highly significant, as were the interactions between species and paints and species and times. The interaction between species and paints is of considerable interest, but the interaction between species and times merely means that different species flew at different times.

The order of species preference for zinc chromate versus Colonex paints is given in Table 3. These results indicate a sharp distinction in landing behaviour between, say, *M. ornatus, M. persicae,* and *B. brassicae* on the one hand, and *H. foeniculi* on the other.

Reflectance spectra of the two paints were measured against a magnesium carbonate standard over the ultraviolet and visible wavelengths in a Beckmann spectrophotometer. The spectra are shown in Fig. 4.

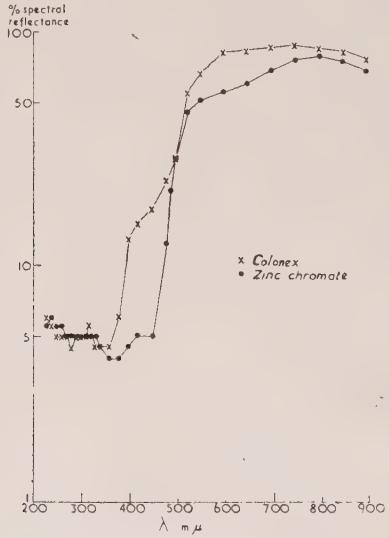

FIG. 4.—Reflectance spectra of zinc chromate and Colonex paints.

DISCUSSION AND CONCLUSION

The landing of alate aphids on traps is the result of a positive response to a colour stimulus (Moericke, 1952, 1953, 1954b, 1955a and b). Pure yellow ("a supernormal sign stimulus") was found by Moericke to be most effective in causing the landing response, but its effect was diminished by dilution of the colour with black or white pigment. Orange and green were less effective landing stimuli, while red, blue, and black traps were ineffective. Some species differed in their response to reflected ultraviolet radiation. Thus *Hyalopterus pruni* Geoff. was more strongly attracted to U.V. reflecting surfaces than to yellow, which had only a weak attraction to this species. Most other aphid species examined were, however, attracted to yellow irrespective of U.V. or infrared reflection.

In experiments with suction traps with different types of borders at ground level, Moericke (1955b) found that white or U.V. reflecting surfaces had a positive repellent effect on several species. Traps surrounded by bare earth (U.V. absorbing) were consistently more effective than those with white or blue borders. Yellow traps surrounded with black (Moericke, 1954b) were less effective than those surrounded by bare earth for most species, but were more effective for *Rhopalosiphum padi* (L.) and *Hyperomyzus lactucae* (L.).

Thus Moericke has shown that aphids respond differentially to radiation from different parts of the spectrum. For most species, yellow is the optimum colour for inducing the landing response, inhibiting locomotion, and inducing probing to take place. White or ultraviolet, on the other hand, have a repellent effect on most species. Moericke (1955a) further postulated that flying aphids need to be in an appropriate behavioural condition ("Befallsflugs") for the landing response to occur.

Eastop (1955) compared catches in yellow traps with catches in adjacent suction traps and deduced that certain species showed a much stronger preference for yellow than others. The catch ratios (yellow/suction traps) for some relevant species were: *Myzus ornatus* 25·0 (1·40), *Brevicoryne brassicae* 11·1 (1·05), *Myzus persicae* 6·4 (0·81), *Lipaphis erysimi* 2·7 (1·43), *Rhopalosiphum maidis* 0·8 (0·09). (The figures in parentheses are the logarithms of the ratios found.) In general, grass and sedge-feeding species were only weakly attracted to yellow.

Heathcote (1957) found significant differences between the ratios of catches in water and suction traps. Yellow traps had a low attraction for *Anoecia corni* (F.), *Pemphigus bursarius* (L.), and *Sitiobium* spp., but a high attraction for *Tuberculoides annulatus* (Hartig).

Although *Eriosoma lanigerum* and *Rhopalosiphum padi* are relatively common species in Auckland, few were trapped during the year. The above results suggest that this may have been due to inadequacy of yellow as a landing stimulus for these species.

When the relative catches of the two types of paint (Table 3) are compared with the results of Eastop (above), it is apparent that the preference of most species for zinc chromate paint closely followed their yellow preference as reported by Eastop. Thus (considering the log ratios), the catch of *L. erysimi* on Colonex versus zinc chromate was about half that of *B. brassicae* or *M. persicae* and about one-third that of *M. ornatus* (a species very strongly attracted to yellow).

When the reflectance spectra of the two paints are compared (Fig. 4), it appears, however, that Colonex was the brighter yellow. Furthermore (except in the near visible region), there was no marked difference in the U.V. reflectance of the two paints. The most striking difference between the paints was in the blue-violet region (360 to 480 mμ), where there was a significantly higher reflectance by Colonex.

Assuming that blue-violet light has an opposite effect to yellow light on the landing response, the different action of the two paints on different species could be interpreted as being due to different thresholds to the mutually opposed blue-violet and yellow stimuli. The above results suggest that blue-violet rejection and yellow attraction tend to occur together since the species most strongly attracted to yellow (according to Eastop) seem to have shown the strongest rejection of the Colonex painted traps.

There are obvious direct effects of weather on aphids. For example, higher temperatures mean shorter life histories and higher rates of multiplication. Little aphid flight occurs during rain. Nevertheless, perhaps the most important effects of climate on aphids are indirect—i.e., by way of the host plants, which may be greatly affected by environmental changes. Aphid reproduction and form determination are to a large extent controlled by nutrition and hence by the physiological condition of the host.

The number of aphids in the air at any time depends upon a complex of factors including population density on crops, rate of alate production, and flight activity. All of these factors are influenced by climate, though to different degrees. Thus, as Johnson (1952) has pointed out, it is necessary to be very circumspect in drawing conclusions concerning the mode of action of climate on aphids solely from trap data, since both population and behavioural factors are involved. Yellow traps give a measure of the relative number of flying aphids alighting at any time, but they do not indicate why the aphids are flying, unless the information is supported by observations of a different kind.

The results indicated that mass seasonal migrations did not occur in this district. The large peak catch in weeks 31 and 32 corresponded with maximum summer populations of aphids on nearby Brassica plants. In fact, these results suggest that winged aphids were being produced all the year round and reached their maximum number when the species concerned were most abundant on their hosts.

This season was an average one so far as general aphid incidence on crops was concerned. Although the catches are not large for the most part, it is instructive to consider them in terms of aphids landing per acre per week. At a conservative estimate, approximately 800,000 winged aphids were landing per acre per week in the month of February. Even in midwinter, some 12,000 aphids were landing per acre per week. Thus, given a source of infection, the introduction of virus disease into any crop would be highly probable. In other words, aphid abundance is unlikely to be a limiting factor in the spread of plant virus diseases from crop to crop.

In conclusion, the results show that the use of Moericke type water traps is quite a feasible procedure for survey work or ecological investigation of most aphid species—especially the common virus vectors which are strongly attracted to yellow. The method is not suitable for use with some species that are weakly attracted to yellow. Caution is

needed in interpreting differences in catches between species, but variations in numbers within species with time appear to be estimated satisfactorily. A disadvantage of the method is the need for frequent inspection and maintenance of the traps (every two to three days). This may preclude their use in remote areas.

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Dr H. R. Thompson (Applied Mathematics Laboratory, D.S.I.R.) calculated multiple correlations with weather data and advised on statistical procedures. Reflectance spectra of paints were measured by Mr B. J. O'Brien (Dominion Physical Laboratory, D.S.I.R.). Miss L. M. Spencer gave technical assistance during the aphid trapping. Dr V. Moericke (Institut für Pflanzenkrankheiten, University of Bonn) kindly demonstrated his trapping technique.

The author gratefully acknowledges this assistance.

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FOODS OF THE AUSTRALIAN OPOSSUM (*Trichosurus vulpecula*, Kerr) IN NEW ZEALAND INDIGENOUS FOREST IN THE ORONGORONGO VALLEY, WELLINGTON

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Summary

The contents of 130 opossum stomachs from animals taken in native forest in the Orongorongo Valley, Wellington, between July 4 1946, and May 24 1947 were examined. A variety of foods was found, the chief being leaves of konini (*Fuchsia excorticata*), northern rata (*Metrosideros robusta*), clover (*Trifolium* spp.), titoki (*Alectryon excelsum*), raukawa (*Nothopanax edgerleyi*), kamahi (*Weinmannia racemosa*), fivefinger (*N arboreum*), and teatree (*Leptospermum* sp.), with the addition of flowers, chiefly northern rata, clover, teatree, and fivefinger in summer, and of various fruits and seeds, chiefly pigeonwood (*Hedycarya arborea*), tutu (*Coriaria arborea*), hinau (*Elaeocarpus dentatus*), kawakawa (*Macropiper excelsum*), and poroporo or bullibull (*Solanum aviculare*), in summer and autumn. There was little and infrequent animal material and it appeared to have been eaten fortuitously. Each stomach contained on the average three kinds of food; the most frequent number of foods was two. The results of field observations and feeding in an enclosure are in agreement with those from the stomach contents and gave additional information. Comparison with a few stomachs from Poverty Bay and previous observations suggest that abundant foods may be eaten more in some districts than in others. Several plants poisonous to other animals were frequently eaten.

Introduction

Brushtailed opossums (*Trichosurus vulpecula*, Kerr) were introduced into New Zealand from Australia and Tasmania, at various times after the middle of last century (Thomson, 1922), and increased until there were enough for large numbers to be trapped for their skins.

Kirk (1920) and Thomson (1922) list foods eaten by opossums, but their statements do not seem to be based on examination of stomach contents. Perham (1928, unpublished*), Kirk (1929, unpublished†) and the Peel Forest Board (1937, unpublished†) examined stomach contents but give scarcely any details of the results. Perham examined 123 stomachs over a period of two months sometime prior to 1928 but

*"Progress report of investigation on the opossum—genus *Trichosurus*—in New Zealand." Appendix D to "The Opossum Industry in New Zealand. State Forest Service." (Unpublished.)

†In letters dated 4th and 5th November 1929, filed in the Department of Internal Affairs.

gives only a general account of the material found, mentioning but few names of the plant species. Kirk (1929) examined 266 stomachs from Kapiti Island over a period of almost a year in 1928-29 but the chief object seems to have been to see whether opossums were destructive to bird life. No details of the plant material found were given. In 1937 the stomach contents of 100 opossums taken from Peel Forest from 15 to 17 July were examined and reported on by the Peel Forest Board. Only a brief general account is given of the foods eaten. Over this period there was considerable public concern that opossums might be destructive to bird life. These investigations were therefore directed more to finding whether opossums ate eggs and fledglings, or plants, than to the particular nature of the plant material.

As opossums are nocturnal animals, it is particularly unsatisfactory to attempt to discover what they eat by watching them, and apart from the study of stomach contents, reliance has to be placed on the damage done to plants. While there has been no conflict of opinion as to the damage done by these animals in orchards, crops, and gardens, and to certain exotic forest species, much doubt has been expressed as to their having any really harmful effect on typical areas of New Zealand indigenous forest. For this reason, when the Department of Internal Affairs was investigating methods of control of opossums, and as far as practicable studying their life history and habits, stomachs of some of the animals trapped were sent to the Botany Division, D.S.I.R., for study, to identify the foods that were being eaten in indigenous forest.

The listing of plants and the trapping were done by Mr L. Pracey of the Wild Life Branch of the Department of Internal Affairs (now of Noxious Animals Division, N.Z. Forest Service) in the course of his investigations; Mr Pracy also made the observations in the field on damage done by opossums, carried out the experiment with opossums in the enclosure, as well as supplying the information on the history of opossums in the valley. The identification of food materials and the account of vegetation of the area were done by the author.

VEGETATION OF ORONGORONGO VALLEY

The work was carried out in Opossum Trapping Block No. 24, Orongorongo Valley, Rimutaka Range, Wellington District. The area trapped extended from the mouth of Brown's Stream (350 ft) down to Wootton Stream (250 ft) and up to the ridges on either side of the river. On the western side there are a few small river flats and the country rises steeply to the Cattle Ridge which is from 1,000 to 1,400 ft high. On the eastern side near the river there are several river flats and a good deal of gently sloping land; the country then rises steeply to the main ridge of the Rimutaka Range, which is here from 2,400 to 2,766 ft high.

The principal trees and shrubs are:

northern rata*	rangiora
pigeonwood	heketara
hinau	wineberry
mahoe	horopito
fivefinger	kamahi

Kamahi is most abundant at altitudes above seven or eight hundred feet. There are large patches of hard and black beech. Not quite so frequent are:

titoki	tree ferns
rewarewa	rimu
putaputaweta	mingimingi
mapau	toro
kawakawa	

Toro is most abundant above 700 ft. Less frequent still are:

miro	kiekie
matai	hangehange
kaikamako	totara
pate	

There are scattered nikaus and in some places a few tawas, and occasional karakas are found up river as far as Browns Stream. There are many ground ferns, many climbers such as supplejack which is abundant, rata vines (*Metrosideros*, spp.), bushlawyer, some clematis, and many epiphytes such as *Astelia solandri*, A. Cunn., *Collospermum hastatum*, (Col.) Skottsb., and puka. Oatgrass or bush rice-grass (*Microlaena avenacea*, (Raoul) Hook. f.) is common on the forest floor, particularly in more open forest.

On the river flats and stream banks tutu, white and red teatree, and konini occur, often with ribbonwood and *Coprosma* spp. growing beneath. On open river and stream flats there are tauhinu, grasses, and herbaceous plants such as clovers, *Hydrocotyle*, spp., bidibidi, and introduced weeds. Hookgrass (*Uncinia australis*, Pers.) is common in the open and under light bush. Poroporo is occasional in open places.

Konini is plentiful on steep faces where the forest floor consists of unstable rock debris.

Above about 2,200 ft there is silver beech forest with such shrubs as pepper tree, stinkwood, and one of the leatherleafs or leatherwoods.

In some places the bush has long been destroyed and second growth is appearing; on the steep western hillside just below Tainui hut, for instance, rangiora, kiekie, and such plants are now growing, and on

*Botanical names are given in Appendix 2, p. 612.

much of the top of the Cattle Ridge young plants of kamahi, five-finger, rangiora, heketara, rewarewa, and ponga (*Cyathea dealbata,* Swartz) are coming in under a canopy of teatree. Above about 1,500 ft on the eastern side there are many large, old earthquake slips in various stages of regrowth. No samples were taken from any places such as these.

HISTORY OF OPOSSUMS IN THE ORONGORONGO VALLEY

Opossums were first liberated in the Wainui-o-mata Valley (the adjacent valley to the west) in 1893 and 1894. It is believed they were also introduced into the Orongorongo Valley during the same period and at various times on the eastern and western sides of the Rimutaka Range, but no definite information on dates is available.

Trapping was carried on in the Orongorongo Valley from 1921 to 1927 under the control of the New Zealand Forest Service, and from 1927 onwards under the control of the Wellington City Council. Closed seasons were observed from 1932 to 1938, but extensive poaching was certainly carried on during those years. Thus the area has been continuously trapped and poached since 1921.

Density of Opossum Population

Little is known of the previous population density but from information gleaned from trappers the density had been heavier before the period of sample (1946-47).

Trapping on an area between Brown and Greens streams and the Orongorongo River and the Rimutaka Ridge was done between 4 July 1946, and 18 July 1947, 1024 opossums being taken, of which 197 were kittens. This area is approximately 230 acres, allowing a 10-chain margin outside the outermost lines.

STOMACH CONTENTS

Six stomachs at a time were taken at intervals of a fortnight over the period 4 July 1946, to 20 May 1947, from a total of 135 opossums. At times bad weather interferred with collecting and unfortunately the winter month of June, 1947, was missed. Sixty-five of the animals examined were trapped below 500 ft, 42 between 500 and 1,000 ft, 16 between 1,000 and 1,500 ft, 6 between 1,500 and 2,000 ft, and one above 2,000 ft. Thus 82% were trapped below 1,000 ft. Five stomachs were discarded because they contained only very small quantities of disintegrated matter.

The stomachs were removed from the opossums as soon as possible after the animals were caught and the contents of each stomach wrapped in a square of cloth and placed in 5% formalin overnight. This was then hung to drain surplus moisture, left for a few days for most of the formalin to evaporate, and forwarded for examination.

On receipt at the laboratory this material was left to dry, because features such as venation then became more conspicuous, and because the leaves had to be compared with herbarium specimens. This method worked well, except for thin leaves like those of *Pratia angulata,* Hook. f. The dried food material kept satisfactorily for as long as a year.

The leaf material was generally finely divided, with the harder and coarser leaves of plants such as northern rata and kamahi more divided than the thinner and softer leaves such as those of konini. There were usually enough scraps of leaf, about 4 mm. square or larger, which could be identified by study of the texture, colour, venation, leaf margins, hairs, oil glands, and other features. Usually it was easy to see which of the more finely divided materials matched the larger identifiable pieces, and to distinguish between the leaf material from several different plant species in one stomach.

A few flower buds and young flowers, particularly of *Nothopanax,* were identified by means of the pollen grains by Miss D. B. Filmer.

Each stomach usually contained about a half to one pint of material.

The frequency of occurrence of the different foods is shown in Table 1. Leaves, flowers, and fruits of the same species have been considered separately; this is necessary as in some plants, such as pigeonwood and titoki, one part is eaten and other parts are neglected.

Notes on Various Foods

Northern rata

Flowers were eaten from the beginning to the middle of January. From the middle of February onwards only young leaves were eaten. In early August some flower buds were eaten.

Fivefinger

Both the leaf-blade and the skin of the petiole were eaten, often both at the same time. The blade was often eaten and not the petiole skin, but only once the petiole skin without the blade. Once the pithy material from the inside of the petiole near its sheath was eaten. The flowers were mostly buds or very young flowers and were identified by their pollen. The pollen did not show definitely whether the flowers were from *Pseudopanax* or species of *Nothopanax,* but Miss Filmer considered that they were probably from *N. arboreum* (which is by far the commonest species near the traps), because of the season of flowering. There was only one fivefinger fruit in the one sample where fivefinger occurred.

Clover

Leaves and flowers of both white and suckling clover were eaten. The flowers were eaten throughout January. A few seeds were eaten by one opossum in the middle of January.

Rangiora

Only young leaves were found in the stomach contents. They occurred from the beginning of October to the beginning of March, with a single record at the end of May. Many pappus hairs were found in two stomachs in early October but no achenes.

Raukawa

Only the leaf-blade was eaten. No part of the petiole was found.

Karamu

Both plants known as karamu (*Coprosma robusta* and *C. lucida*) grow in the Orongorongo Valley. It was not always possible to identify the species eaten, but *C. robusta* was tentatively identified twice and *C. lucida* once.

Bushlawyer

Generally only young leaves were eaten. The fruits were eaten at the end of January.

Wineberry

Only a very small quantity of leaf was found in any stomach.

Trichomanes venosum

One frond of this filmy fern was found in a stomach.

Teatree

It was not possible to distinguish which species of *Leptospermum* had been eaten. The flowers were eaten towards the end of January, with a few scraps in late October.

Pigeonwood

Usually only the flesh of the fruit was eaten but occasionally the stones also were swallowed, sometimes whole and sometimes crushed. Two samples obtained on the 23 August contained many broken pieces of the fruit shells though there was no sign of kernel. The opossums may have found some old fallen fruit or perhaps some green fruit which are on the trees at this time of the year. Pigeonwood fruit was found from the middle of January till the 23 April, and twice in August.

Tutu

Fruits were found from the middle of March until the 24 April with a single fruit occurring in an animal late in August. The fruits were often much crushed.

TABLE 1.—Foods in 130 Opossum Stomachs.

Leaves	Number of Occurrences						
	July 4-Aug. 23 Winter 20 stomachs	Sep. 4-Oct. 18 Spring 24 stomachs	Oct. 28-Dec. 15 Late spring to early summer 20 stomachs	Jan. 5-Feb. 18 Summer 24 stomachs	Mar. 3-Apl. 8 Autumn 23 stomachs	Apl. 22-May 24. Late autumn 19 stomachs	July 1946-May 1947. TOTAL 130 stomachs
Fuchsia excorticata, konini	4	5	9	11	6	6	41
Metrosideros robusta, rata	6	9	5	6	8	4	38
Alectryon excelsum, titoki	4	9	5	5	3	8	34
Weinmannia racemosa, kamahi	6	7	3	5	3	1	25
Nothopanax arboreum, fivefinger	8	5	3	4	2	2	24
Trifolium spp., clover	—	2	3	10	4	1	20
Brachyglottis repanda, rangiora	—	3	4	4	1	1	13
Leptospermum sp., teatree	3	1	3	5	—	—	12
Coprosma sp., karamu	3	1	1	1	—	1	7
Muehlenbeckia australis	—	—	—	3	2	1	6
Rubus sp., bushlawyer	1	1	1	1	2	—	6
Nothopanax edgerleyi, raukawa	1	2	—	—	1	1	5
Aristotelia serrata, wineberry	2	1	—	2	—	—	5
Elaeocarpus dentatus, hinau	—	2	—	1	1	—	4
Pratia angulata	2	—	—	1	—	—	3
Acaena sanguisorbae, bidibidi	—	1	—	—	1	—	2
Ferns	—	1	1	—	—	—	2
Grasses	—	2	—	—	—	—	2
Hydrocotyle moschata	2	—	—	—	—	—	2
Metrosideros diffusa, white rata	—	1	—	1	—	—	2
Metrosideros scandens, climbing rata	1	—	—	—	1	—	2
Crepis sp., hawkweed	—	—	—	—	—	1	1
Griselinia sp., puka, broadleaf	—	—	—	—	1	—	1
Hcheria sp., lacebark	—	—	—	—	1	—	1
Melicope ternata, wharangi	—	—	—	—	1	—	1
Melicytus ramiflorus, mahoe	1	—	—	—	—	—	1

Metrosideros perforata, white rata	—	—	—	1	—	—	1
Schefflera digitata, pate	—	—	—	—	—	1	1
Trichomanes venosum, filmy fern ...	—	1	—	—	—	—	1
Uncinia sp., hookgrass	1	—	—	—	—	—	1
Unidentified	1	3	—	5	1	1	11
TOTALS	46	57	38	67	39	30	277
Fivefinger petioles	5	4	1	1	0	0	11
Flowers and Buds							
Metrosideros robusta, rata	1	—	—	10	—	—	11
Trifolium spp., clover	—	—	—	7	—	—	7
Leptospermum sp., teatree	—	—	1	3	—	—	4
Nothopanax arboreum, fivefinger	1	1	1	1	—	—	4
Weinmannia racemosa, kamahi	—	—	2	—	—	—	2
Fuchsia excorticata, konini	1	—	—	1	—	—	2
Leontodon sp., hawkbit	—	—	—	—	—	1	1
A composite herb	—	—	—	1	—	—	1
Unidentified	—	—	1	2	—	—	3
TOTALS	3	1	5	25	0	1	35
Fruit and Seeds							
Hedycarya arborea, pigeonwood	2	—	—	8	8	1	19
Coriaria arborea, tutu	1	—	—	1	5	3	10
Elaeocarpus dentatus, hinau	—	—	—	—	—	9	9
Macropiper excelsum, kawakawa	—	—	—	—	5	—	5
Solanum aviculare, poroporo	—	2	—	—	1	2	5

TABLE 1.—Foods in 130 Opossum Stomachs (contd.).

	Number of Occurrences						
	July 4-Aug. 23 Winter 20 stomachs	Sep. 4-Oct. 18 Spring 24 stomachs	Oct. 28-Dec. 15 Late spring to early summer 20 stomachs	Jan. 5-Feb. 18 Summer 24 stomachs	Mar. 3-Apl. 8 Autumn 23 stomachs	Apl. 22-May 24. Late autumn 19 stomachs	July 1946-May 1947. TOTAL 130 stomachs
Carex spp., sedge	2	—	1	—	1	—	4
Fuchsia excorticata, konini	—	—	—	2	—	2	4
Uncinia sp., hookgrass	1	—	1	1	1	—	4
Grasses	—	—	—	1	1	1	3
Rubus sp., bushlawyer	—	—	—	3	—	—	3
Astelia solandri	—	—	—	—	—	2	2
Brachyglottis repanda, rangiora	—	2	—	—	—	—	2
Freycinetia banksii, kiekie	2	—	—	—	—	—	2
Acaena sanguisorbae, bidibidi	—	—	—	1	—	—	1
Cerastium sp., mouse-eared chickweed	—	—	—	—	—	1	1
Collospermum hastatum	—	—	—	—	—	1	1
Knightia excelsa, rewarewa	—	—	1	—	—	—	1
Leontodon sp., hawkbit	—	—	—	—	—	1	1
Nothopanax arboreum, fivefinger	—	—	—	1	—	—	1
Olea sp., maire	—	—	—	—	—	1	1
Podocarpus sp., miro probably	—	—	—	—	—	1	1
Pseudopanax crassifolium, lancewood	1	—	—	—	—	—	1
Pseudowintera sp., horopito	—	—	—	—	—	1	1
Rhipogonum scandens, supplejack	—	—	—	—	1	—	1
Solanum nigrum, nightshade	—	—	—	—	1	—	1
Suttonia australis, mapau	—	—	—	—	1	—	1
Trifolium sp., clover	—	—	—	1	—	—	1
Unidentified	1	—	—	—	1	—	2
TOTALS	10	4	3	19	26	26	88

Hinau

The skin and mealy part of the fruit were eaten from the end of April to the end of May.

Kawakawa

Fruits were eaten from the middle of March to the end of April.

Poroporo

At the beginning of October one seed was found in each of two samples. In the latter half of April considerable quantities of fruit skins, but no seeds were present in three stomachs.

Maire (*Olea* sp.)

At the end of May one stomach contained the skin of a fruit apparently from a species of *Olea*.

Miro or matai

Skin and flesh of the fruit of either miro or matai was found. It seemed more likely to be miro.

Lancewood

One fruit was found.

Supplejack

Only the skin and flesh of supplejack fruit was eaten.

Kiekie

Seeds only were found.

Rewarewa

Parts of the pod only were found.

Collospermum hastatum

A gelatinous material of vegetable origin found in three stomachs, once in considerable quantities was identified as the base of the leaves of *Collospermum hastatum*.

Other unidentified vegetable material was some fluffy or hairy material (4)* a few buds (2), a scrap of moss (1), and miscellaneous materials (5). The quantities were small.

*Number of times of occurrence in parentheses.

Occasionally a few dead twigs (7), dead or dying leaves (20), small chips of wood (3), scraps of dead bark (2), dry grass glumes or scales of tree ferns (7) were found. These were never numerous and were possibly swallowed inadvertently. There was no difficulty in distinguishing dead or dying leaves, such as those of miro (7) and teatree (7), from proper foods; they were always much fewer, yellow or brown and had never been chewed.

In ten stomachs material was found which was identified by officers of the Dominion Museum as follows: caterpillars of moth (probably noctuid), damsel fly remains, cicada (*Melamsalta muta*), portions of stick insect legs (twice), dipterous fly (twice), fly, cicada body, weta mandible. The quantities were small and seemed to have been eaten by accident.

Number of Foods Eaten per Opossum

The average number of foods found in a stomach was three, the most frequent number, two. The frequency of the numbers of food per stomach is shown in Table 2.

TABLE 2.—Number of Foods per Stomach.

Number of foods per stomach	Number of occurrences
1	24
2	38
3	22
4	22
5	11
6	3
7	5
8	3
9	2
Average 3·1	

FIELD AND ENCLOSURE OBSERVATIONS

Throughout the year field observations were made in the area to determine what foods were being eaten by opossums. As opossums are nocturnal feeders the only evidence available was the damage to the plants. It took at least three to four months experience before opossum damage could be distinguished with certainty from that due to other animals, birds, and insects. The use of field glasses and climbing irons was necessary.

A wire-netting enclosure 12 ft by 14 ft and 15 ft high was erected over a few small trees and shrubs and three or four opossums were kept in it from the 7 February to the 1 May. They were fed on several leafy branches of different species daily and also on fruits and berries. This enabled a further check to be made on the results of field observations and stomach examinations.

Field Observations

Leaves

Group A. From field observations the plants of this group seem to provide the leaves which seemed to be most preferred for food. They are given in what was judged to be the order of preference: Konini, northern rata, titoki, fivefinger, raukawa, kamahi, tutu, hinau, wineberry, white teatree, rangiora, black maire, white maire, mairetawhake, mountain panax (*Nothopanax sinclairii,* (Hook. f.) Seem.), pate, ngaio, bushlawyer, lacebark, lowland ribbonwood, and toro—at higher altitudes.

Group B. These plants are eaten by opossums and sometimes severely damaged, but not as much as in the preceding group: Broadleaf, kaikomako, kawakawa, kohekohe (south of trapped area), mahoe, puka, pukatea, pokaka, rata vine, totara.

Group C. These are not often eaten, but severely damaged plants are sometimes found: *Astelia* sp. (young plants), *Coprosma lucida, C. robusta,* lancewood, leatherwood, miro, mistletoe, native passionfruit, pigeonwood, putaputaweta, small rata vine (*Metrosideros perforata,* (Forst.) Rich.), tarata.

Flowers and Buds

Flowers and buds of the following plants were eaten: *Astelia* sp., koromiko, lowland ribbonwood, mahoe, mairetawhake, *Metrosideros* spp., mountain flax (*Phormium colensoi,* Hook. f.) nikau, northern rata, white teatree.

Fruits and Seeds

The following were eaten: *Astelia* sp., black maire, bushlawyer, fivefinger, hinau, horopito, kaikomako, karaka, kawakawa, kiekie, konini, lowland ribbonwood, matai, miro, native passionfruit, nikau, pate, pigeonwood, pokaka, poroporo, supplejack, tawa, titoki, totara.

Ferns

The following ferns were sometimes eaten: *Asplenium falcatum,* Lam.; *A. flaccidum,* Forst. f.; *A. lucidum,* Forst. f.; *Blechnum procerum,* (Forst. f.) J. Anderson; *Cyathea smithii,* (Hook.) Domin (soft tree fern); *C. medullaris,* Swartz (black tree fern); *Cyclophorous serpens,* C. Christen.; *Pellaea rotundifolia,* Hook.; *Polypodium diversifolium,* Willd.; *Polystichum richardi,* Hook. f.; *Pteridium esculentum* (Forst. f.) Diels (bracken).

Not Eaten Though Present

The following plants occurred in the field, but showed no signs of possum damage: black beech, hard beech, silver beech, black matipo, *Coprosma areolata,* Cheesem.; *C. rhamnoides,* A. Cunn., *C. australis,*

(Rich.) Robinson, stinkwood, *Clematis* sp., hangehange, heketara, horopito, peppertree, kiekie, koromiko, *Leucopogon fasciculatus*, matai, mapau, *Muehlenbeckia australis*, (Forst. f.) Meissn., *Pratia angulata*, ramarama, rohutu, red teatree, rewarewa, rimu, supplejack, wharangi.

Enclosure Experiment

Leaves of the following species were eaten: *Coprosma robusta*, *C. lucida*, fivefinger, hinau, kaikomako, kamahi, konini, lancewood, mahoe, mapau, miro, native passionfruit, northern rata, rata vine, white rata (*Metrosideros diffusa*, (Forst.) Oliver), pate, puka, rangiora, tarata, titoki, toro, white teatree, wineberry.

The same fruits were eaten as those noticed in the field, except those of *Astelia* sp., fivefinger, and black maire. Konini berries were eaten greedily and in great quantities. In addition, fruits of raukawa and the karamus were eaten.

The following foods, though available, were not eaten in the enclosure: black beech, hard beech, silver beech, *Coprosma areolata*, *C. australis*, *C. rhamnoides*, *Cyathodes acerosa*, heketara, horopito koromiko, putaputaweta, rewarewa, rohutu, tarata, tawa; *Asplenium bulbiferum*, Forst. f., *A. falcatum*, *A. lucidum*, *Adiantum* sp. (maidenhair), *Blechnum lanceolatum*, *B. procerum*, *Dryopteris pennigera*, C. Christen., *Hymenophyllum* spp., *Pellaea rotundifolia*, *Polypodium diversifolium*, *Polystichum richardi*, *Pteris tremula*, R.Br., *Leptospermum* species. Field observations and feeding trials show that it is the leaves of only kanuka or white teatree that are eaten, and then only the young leaves, a point that was not evident from the stomach contents. In autumn the opossums in the enclosure would not eat the teatree fed to them.

Discussion

Comparison between Field Observations and Stomach Content

Many people have been unwilling to accept that any of the defoliation or damage that may be shown in the native bush could be due to opossums, and suggest that birds, insects, or disease may be responsible. They have been able to refer to the authoritative statement (Kirk, 1920) that the damage done by opossums in the New Zealand forests is negligible. It is worthwhile, therefore, to consider how well the conclusions made in the field correspond with the evidence from the stomach contents.

All the leaves of trees, shrubs, and other bush plants found in stomachs were noted as eaten in the field or enclosure with the exception of wharangi and *Trichomanes venosum*, each of which occurred only once, and *Muehlenbeckia australis*. Only a few scraps of *T. venosum* were found in the stomachs. Wharangi only occurs in the southern part of the opossum block, an its rare. *M. australis* is a climber or scrambler and often not readily accessible for close observation.

Of the herbaceous or grassy plants, of which clover was by far the

most frequently occurring, that were found in the stomachs none were observed as eaten in the field, but the patches of grass and herbs, chiefly at stream edges, were not closely examined for signs of opossum feeding. The investigations were primarily into the effect on native bush; in any case the story would be complicated by the grazing of deer, goats or other animals.

Of the 21 plants of which leaves were not found in the stomach contents but which were noted as being damaged, five (ngaio, maire-tawhake, kohekohe, mistletoe, and leather-leaf) were not in the neighbourhood of the possum traps; eight (lowland ribbonwood, maire, pukatea, toro, karaka, pokaka, tarata, and nikau) were in the neighbourhood of traps fewer than ten times. Their failure to appear in the stomach contents cannot, however, be accepted as evidence that they are never eaten; field evidence suggests that, of these eight, only lowland ribbonwood and maire are among the preferred foods, and might have been expected to appear in the stomachs. Three (totara, miro, lancewood) were in the neighbourhood of the traps from 10 to 30 times, but of these miro and lancewood were not damaged to any extent, and totara seldom damaged at all. Pigeonwood leaves were very rarely eaten in field or enclosure—infrequently enough to occasion no surprise that, though occurring 81 times near the traps, it did not occur in the stomachs.

Only young leaf material of rangiora was found in the stomachs and only young leaves were noted as eaten in the field and enclosure.

If comparison is made between the rankings according to the percentage of times eaten of the leaves shown in Table 3 (excluding clover, which was not ranked in field observations) with the rankings given from field observations there is good agreement, the correlation coefficient being 0·8061 which is highly significant. As shown previously most of the rest of those species which field observations showed to be eaten occurred so infrequently near the traps, or were damaged so seldom that they could be expected to occur in these stomachs only by chance.

However, in some cases there seemed less agreement. Tutu leaves were eaten in both field and enclosure and were considered from field evidence as being among the preferred foods in Group A. But though the plant occurred near the traps 36 times no trace of leaves occurred in the stomachs. That its leaves may be eaten is definitely shown by the fact that one of the Poverty Bay stomachs was full of leaves (see Appendix). Field evidence also shows that young shoots are split down and the pith eaten by opossums.

Karamus were on field evidence considered as not eaten to any extent (Group C) but the percentage of times present in stomachs to times available was greater for these than for wineberry or pate, the plants considered as being in the preferred group.

There was no evidence from stomach contents, field, or enclosure, that leaves of rimu, beeches, rewarewa, kawakawa, supplejack, or heketara, all of which were found near traps over 30 times, were eaten.

TABLE 3—Percentage of Times of Eating of Leaves.

	Foods not near traps included					Foods not noted near traps excluded				
	Times eaten as percentage of times available	Times available near traps	Times present in stomachs	Times expected	χ^2	Times eaten as percentage of times available	Times available near traps	Times present in stomachs	Times expected	χ^2
Fuchsia	**70·7**	58	41	18·3	28·1	**65·4**	49	32	12·9	28·3
Clover	**62·5**	32	20	10·1	9·7	**55·6**	27	15	7·1	8·8
Titoki	**61·8**	55	34	17·4	15·6	**55·3**	45	24	11·9	12·3
Raukawa	**55·5**	9	5	2·8	1·7	**42·8**	7	3	1·8	0·8
Rata	**45·3**	84	38	26·5	5·0	**41·0**	78	32	20·3	6·7
Kamahi	37·9	66	25	20·8	0·8	**31·7**	60	19	15·8	0·7
Fivefinger	**27·6**	87	24	27·4	0·4	**21·3**	80	17	21·0	0·8
Teatree	17·4	69	12	21·8	4·5	**16·2**	68	11	17·8	2·6
Rangiora	11·6	112	13	35·4	13·8	**10·8**	111	12	29·2	10·1
Wineberry	**7·9**	63	5	19·9	11·3	**4·9**	61	3	16·1	10·6
Hinau	**6·2**	55	4	20·5	13·6	**4·7**	64	3	16·9	11·4
TOTAL		700	221	220·9	104·5		650	171	170·8	93·1
Expected percentage	**31·6**					**26·3**				

$p < 0·01$ $p < 0·01$

However, one stomach from Poverty Bay was full of rewarewa leaf material, showing it may be eaten under different circumstances.

Of those fruits eaten in the field and enclosure but not found in the stomach, only titoki and karamus were at all abundant near traps. Karamu fruits were seldom eaten in the field. Although konini berries were eaten greedily in the enclosure they did not appear very often in the stomachs. This is, no doubt, accounted for by the fact that most of the berries were knocked from the trees by a great storm over the week-end of the 14-15-16 February—the time when most of the berries are ripening; berries, abundant before, were difficult to find afterwards.

Generally it may be stated that there is good agreement between the stomach contents and field observations.

Food Preferences as Shown by Stomach Contents

As some plants that were eaten were found near trapped opossums far more often than others—for instance, rangiora was near at hand as often as 112 times and raukawa only 9 times—it is obvious that the opossums had better opportunity to eat some foods than others and that a list of the frequencies of occurrences of foods does not necessarily show which foods, if any, are preferred. However, for each trap a list had been made of adjacent plants so that the number of times the food was eaten could be expressed as a percentage of the number of times the food was available. (See Table 3).

Occasionally foods were eaten that were not noted as present in the neighbourhood: in compiling Table 3 these foods were considered as being both eaten and available, but results are also given excluding these cases. There are great differences in the percentage of time leaf foods are eaten, ranging from 6·2% for hinau leaves to 70·7% for konini leaves. A χ^2 test shows these differences to be very highly significant, with leaves of konini, titoki, clover, and rata eaten more than the average and leaves of teatree, rangiora, hinau, and wineberry less often than the average. If those cases where foods were eaten but not noticed in the vicinity of the traps are ignored the pattern that emerges is the same, except that teatree leaves no longer appear to be eaten significantly fewer times than the average.

Mahoe and pate occurred near the traps 72 and 10 times respectively; each was eaten only once, though in neither case was a tree noted near the trap. If mahoe is regarded as having been eaten once and available 73 times it was eaten in 1·4% of times available, fewer times than any food in Table 3 and quite significantly less than the average.

The leaves of some frequently occurring plants were never found in stomachs. These (with the number of times of occurrence near traps) were pigeonwood (81), heketara (57), supplejack (55), kawakawa (47), rewarewa (40), beeches (37), tutu (36), puteputaweta (32), rimu (30), mapau (30). Grasses were fairly frequent and come in this group.

Other plants not quite so frequent whose leaves were not eaten were horopito (22), lancewood (19), miro (18), totara (15), kaikomako (12), and matai (11). There were also various species of *Coprosma*. It seems that these, if eaten at all, are not preferred foods.

Plants listed fewer than ten times whose leaves were not eaten were tawa, sedges, tauhinu, karaka, kiekie, hangehange, broadleaf, *Gunnera* sp., ramarama, rohutu, *Nertera* sp., toro, hookgrass, pukatea, golden akeake (*Olearia paniculata*, (Forst.) Cheesem., tarata, poroporo, maire, and nikau. There is insufficient evidence to conclude that they are not eaten by possums, but it may be noted that poroporo, tarata, and hangehange were found growing almost as frequently as raukawa.

Fivefinger leafblades and petioles were found together in the same stomachs 10 times, leafblades alone 13 times, and petioles alone once. The preference for leafblades is highly significant.

The times eaten as percentage of times available for the flowers and fruits for those plants for which there was enough information is shown in Table 4.

TABLE 4.—Percentage of Times of Eating of Flowers and Fruits.

	Times found in stomachs	Times available near traps	Times eaten as percentage of times available
Rata flowers	10	12	83
Kawakawa fruit	5	8	63
Hinau fruit	9	15	60
Clover flowers	7	13	54
Pigeonwood fruit*	17	32	53
Tutu fruit*	9	23	39
Teatree flowers	3	16	19

*Stray occurrences in late winter omitted; no information of how often fruit was available then.

When both rata flowers and rata leaves were available flowers alone were eaten 8 times, leaves alone once, and flowers and leaves together twice. Numbers were too small to test for a significant difference.

Seasonal Changes

A χ^2 test made on each of the eight most important leaf foods (konini, titoki, clover, northern rata, kamahi, fivefinger, teatree, and rangiora) over the six seasonal periods did not show any significant differences in the number of times they were eaten at any season.

However, the percentages for fivefinger leaves of times eaten to times available runs from 61% in late winter through 31, 33, 19, 12, to 16 in late autumn, which is in keeping with the field observation that they are eaten more frequently in winter and early spring.

Likewise the percentage for fivefinger petioles of times eaten to time available runs from 38% in winter, 25% in spring, 11% to 5% in summer, to 0% in autumn. Numbers were too small for a test of significance, but the percentages are in keeping with field observations that petioles are eaten more often in winter and early spring, when the ground beneath trees is often littered with nipped off, fallen leaves.

As koninis are deciduous leaves are not generally available in mid-winter, though the period for which they are bare varies with the locality, those at higher altitudes coming into leaf later than those lower down. But as no opossums were trapped near koninis during the leafless period no seasonal difference was apparent.

As might be expected there were significant changes in the types of food eaten during the year. Leaves formed the most important part of the opossum diet; they provided the greatest variety of foods throughout the year, particularly in summer, but less so than usual in autumn. Flowers were of importance only in summer when on an average one kind occurred in each stomach; they scarcely occurred at all in early spring or autumn. Fruits were of importance in late autumn when they were of almost as much importance as leaves; they were naturally infrequent in spring and early summer. There was a significant increase in the total variety of foods eaten in summer, mainly owing to the greater number of times flowers were eaten.

Late winter to early summer: The chief foods were leaves with very occasional flowers, which became more frequent towards summer. Fruits were moderately frequent in winter, scarcer in spring and early summer.

Summer: The opossum ate the greatest variety of food of any time of the year. Leaves were the most frequent foods, significantly more frequent than at any other time. Flowers, mostly northern rata and also teatree and clover, were more frequent than at any other time. Fruits were again moderately frequent. The chief fruit was that of the pigeonwood.

Early Autumn: Although still most important, leaves were not quite so frequent as earlier and flowers were not present at all. Fruit was eaten much more frequently. The chief fruit was still that of pigeonwood with those of tutu and kawakawa next in importance.

Late autumn: Leaves, though less frequent than at any other time, were still the most frequently occurring foods .Flowers were, of course, negligible. Fruits occurred almost as frequently as leaves, and were more frequent than at any other time of the year. Pigeonwood occurred once and hinau berries were now the most important fruit. Tutu fruit was still eaten but only towards the beginning of the period.

Mid-winter.: No stomachs were taken in June 1947, but four from this possum block taken in June, 1948, suggest that fruit may still be of importance in winter.

Poisonous Plants

Plants known to be poisonous to other animals were eaten, and some were important foods.

Fruit of tutu were eaten fairly frequently in season and twice formed the greater part of the stomach contents. The hard part of the fruits were often crushed to pieces. In the field young shoots of tutu were found to be split open by opossums eating the pith and extensive defoliation of plants was observed. Both young shoots and fruit of tutu (but not the accompanying fleshy calyx) are known to be highly poisonous to many animals, and leaves rather less so, but they apparently have no harmful effect on opossums.

Rangiora leaves are known to be poisonous to horses, but the young leaves often occurred in the opossum stomachs, sometimes in fairly large quantities.

There are ngaio trees in the valley further south than the trapped area, and leaves of these had been eaten. Ngaio leaves are highly poisonous to many animals.

Pigeonwood leaves are known to be poisonous, and though evidently generally avoided, were eaten on a tree in the enclosure after opossums had been kept in captivity there for several months.

It is reported by White (1948) that in Queensland the leaves of the highly poisonous *Erythrolobium chlorostachys* are a favourite food of opossums (species not named) and that in Western Australia native marsupials eat several poisonous plants with impunity.

Comparison with Previous Work

In comparing the present results with previous work it must be remembered that previous work was done in different localities and that some plants abundant in one area may be scarce or lacking in another; that there is not always reference to the time of the year in which observations were made; that often no mention was made of the part of the plant eaten.

Various foods found in these stomachs have not been recorded before; the most important new records are titoki leaves, rangiora leaves, teatree leaves, and raukawa leaves, tutu fruit, kawakawa fruit, poroporo fruit, and (from Poverty Bay) *Blechnum procerum*, rewarewa leaves and tutu leaves.

Foods that appeared frequently and have been recorded before are hinau fruit, konini leaves, kamahi leaves, northern rata, bushlawyer leaves, and clovers. "Broad gum, *Panax* sp." presumably a *Nothopanax*, is recorded as eaten in Southland by Thomson. Foods which appeared less frequently that have been recorded before, are wineberry leaves,

pate leaves, mahoe leaves, *Griselinia* leaves, miro berries, supplejack berries, pokaka berries (winter 1948) and bidibidi. The berries of haupara (apparently an araliad, perhaps lancewood) were recorded as being eaten in Peel Forest. Native passionflower was recorded as being eaten on Kapiti, presumably the leaves.

Several of the less frequent foods have been regarded as favourite foods elsewhere. Although both Kirk and Thomson recorded leaves and young shoots of mahoe as being eaten and the Peel Forest Board Report considers it one of the two favourite foods, it was, even though common in the Orongorongo Valley, found in only one stomach in this investigation; and though noted in the field as occasionally considerably damaged by the eating of young leaves, it could by no means be classed among the most preferred foods. Nor could leaves of pate (recorded under the alternative name patete), the other principal food in Peel Forest which is also recorded by Perham and by Kirk (1920) as being eaten, be classed as a favourite food, though field evidence and stomach contents suggested it was preferred to mahoe leaves.

Broadleaf is a name which may be given to both *Griselinia lucida* and *G. littoralis*. Kirk records *G. lucida* as being eaten, and Perham says that in the Catlins, Otago, broadleaf (*G. littoralis*) is the main source of food. Leaves of kapuka (*Griselinia littoralis*) are reported to be one of the chief foods in one part of the Peel Forest. Only one or two opossums were trapped in the neighbourhood of *G. littoralis* in the Orongorongo Valley so that no conclusions can be drawn as to its status as a food there. Field evidence showed that both leading shoots and young leaves of *G. lucida* (puka) and *G. littoralis* (broadleaf) were eaten; but if *G. lucida*, which is common at lower levels in the Orongorongo Valley, had been a food much preferred above others it would have been expected more than the once that *Griselinia* sp. occurred.

Miro and supplejack berries, which have been recorded as important foods, each occurred only once in the stomachs. No possums were trapped in the neighbourhood of miros during the main fruiting season, so that no conclusions concerning the berries can be drawn from the stomach contents; field evidence showed them to be important. But supplejack has a long fruiting season, the fruit being most abundant in mid- and late summer, a time when opossums were trapped in the neighbourhood of the vines. The fruits, therefore, would be expected to have occurred much more frequently if they had been a much-liked food. It may be compared with poroporo, which has a similar type of fruiting period; the fruit was eaten more frequently than those of supplejack, though the plant is much less common.

Various foods previously recorded as eaten were not found in the stomach contents. Kurekure (*Aciphylla colensoi*, Hook. f.) or spear grass, eaten at Peel Forest, kohekohe and southern rata (*Metrosideros umbellata*, Cav.) are not in this area. Karaka leaves, tarata leaves, and nikau berries have been recorded as having been eaten but are not particularly common in the area investigated and would not necessarily

be expected to be found in the stomachs unless they were very highly preferred; field evidence showed that all three are eaten. Putaputaweta is reported to be one of the chief foods in parts of Peel Forest; it was not found in any of the stomachs in the Orongorongo Valley. Perham also mentions that the leaves of *Nothofagus* are eaten; the only ones found in this investigation were a dead leaf in each of two stomachs. Both putaputaweta and beeches were fairly frequently near the opossum traps.

Konini was not mentioned as being eaten in the Peel Forest Report, though present, but would not be expected as the trees would be leafless at the time of the year when stomachs were taken.

The statement by Thomson that opossums are not grass eating animals is confirmed. Grasses were only eaten twice and then only a few scraps. The opportunities for eating grass in the Orongorongo Valley were considerably greater than for eating clovers. It may be noted that in the Peel Forest Report it is said "In 14 opossums . . . the stomach contents appeared to be a mixture of finely minced leaves and grass." As the grass was not identified with certainty, its identification may be doubted in view of the fact that grass was so minor a food elsewhere and that the stalks of clover leaves in opossum stomachs are very easily mistaken for grass without examination with a lens. But it may be noted that one of the 12 stomachs from Poverty Bay, although containing only a small quantity of grass, had considerably more than any of the Orongorongo stomachs.

Perham states that in many instances he found insects and grubs, usually associated with rotten wood or grub-chewed balls of wood. He was not sure whether the wood was taken inadvertently in search for grubs or whether it was eaten occasionally. No such association of grubs and rotten wood was found in this investigation. In two cases the wood found was chips of hard, undecayed wood and in the third it was rather rotten. There was no animal material in these stomachs.

There was no evidence of any barkbiting shown in the stomach contents. The only bark was four dead scraps, found twice. Perham mentions that he found evidence of bark in stomachs only once.

Bits of gravel and outer bark of matai were found in a few stomachs in Peel Forest. Gravel was found in only one Orongorongo stomach but it was plentiful there.

Kirk found in 2 out of 85 stomachs, portions of unfledged birds, such as would be derived from eggs nearly hatched, and Perham quotes Captain Sanderson as having found bird feathers (but there was no indication of other animal matter) in some stomachs. Perham himself had identified no matter other than of vegetable origin, excepting insects, opossum fur, and a small piece of bone. There was nothing to show that opossums ate birds or birds' eggs in any of the stomachs examined in this investigation.

CONCLUSIONS

These investigations support the view previously expressed that Australian opossums live on vegetable material, and that animal material is fortuitous and exceptional. The principal foods were leaves, which were eaten throughout the year; some flowers were eaten in summer, and from the end of summer to the beginning of winter, fruits were eaten frequently. A fair variety of foods was eaten but there was a marked preference for some, and it seems probable that some plants are not being eaten at all, or at least very seldom.

The conclusions drawn from the stomach contents agree well with observations made in the field. However, in this investigation, which depended for material on a project not primarily designed for study of stomach contents, it was possible to deal with only a limited number of stomachs. The number was too small to gain much information about those less frequent plants which did not seem to be particularly preferred, yet some of which were shown by field evidence and the enclosure experiment to be eaten, or to establish seasonal differences in the eating of some foods which are indicated by the field and enclosure evidence.

Generally the opossums appeared to have eaten foods from the immediate neighbourhood in which they were trapped. (This was so also in Peel Forest.)

Comparison of the Orongorongo material with that from Poverty Bay and with previous observations indicates that a food which is unimportant though abundant in one district, may be important elsewhere.

As few stomachs were taken near important timber trees, there is little evidence to show what damage the opossums were doing to them. Beeches and rimu were apparently not eaten, but field evidence showed that totara was sometimes much damaged. It may be pointed out that the tree of which the leaves appear to be most sought after, konini, grows on shingly river and stream banks, water courses, and certain types of steep faces in the bush, where it undoubtedly helps to control erosion.

APPENDIX 1

SAMPLES OF JUNE 1948

The stomachs of 4 opossums trapped somewhere in the Orongorongo trapping block in June 1948, were available and were examined. The goods occurring were pokaka berries (3 times), fruit of poroporo, seeds of *Coprosma* sp., and leaves of titoki, konini, and kamahi; each of the foods other than pokaka berries occurred once.

POVERTY BAY SAMPLES

The stomach contents of twelve opossums trapped during September 1947, in bush and second growth neighbouring on grassland in the Parahaka district, Poverty Bay, were also examined. The foods present

were (with the number of occurrences in parentheses): fivefinger leaves (5), *Blechnum procerum* leaves and scales (4), pine needles (2), pine pollen (3), raukawa leaves (3), clover leaves (2), rewarewa leaves (2), leaves, probably of Douglas fir (*Pseudotsuga taxifolia*, (Poir.) Britt. ex Sudw.) (1), tutu leaves (1), small herbaceous plant (1), grass leaves (1), sorrel leaves (*Rumex acetosella*, L.) (1), scales of a fern (1), decayed wood (1).

One stomach was almost filled with pollen and scraps of pollen cones and a few leaf scraps of a pine. Tutu, rewarewa, and the probable Douglas fir leaves, each formed the entire contents of a stomach. The amount of grass was not great, perhaps almost a dessertspoonful in a single stomach.

APPENDIX 2

List of Alternative Common Names and Botanical Names of Plants

Beech, black	*Nothofagus solandri*, (Hook. f.) Oerst
beech, hard (clinker beech)	*N. truncata*, (Col.) Ckne.
beech, silver (Southland beech)	*N. menziesii*, (Hook. f.) Oerst.
bidibidi (piripiri, hutuwai)	*Acaena sanguisorbae*, Vahl
broadleaf (papaumu, kapuka)	*Griselinia littoralis*, Raoul
bushlawyer	*Rubus* sp.
clover, suckling	*Trifolium dubium*, Sibth.
clover, white	*T. repens*, L.
fivefinger	*Nothopanax arboreum*, (Forst. f.) Seem.
hangehange (pigplant, Maori privet)	*Geniostoma ligustrifolium* A. Cunn.
heketara	*Olearia rani*, (A. Cunn.) Druce
hinau (lily-of-the-valley tree)	*Elaeocarpus dentatus*, Vahl
horopito	*Pseudowintera axillaris*, (Raoul) Dandy
kaikomako	*Pennantia corymbosa*, Forst.
kamahi	*Weinmannia racemosa*, Linn. f.
karaka	*Corynocarpus laevigata*, Forst.
karamu	*Coprosma lucida*, J. & G. Forst., and *C. robusta*, Raoul
kawakawa (native pepper, pepper tree)	*Macropiper excelsum*, (Forst. f.) Miq.
kiekie (gigi)	*Freycinetia banksii*, A. Cunn.
kohekohe	*Dysoxylum spectabile*, Hook. f.
konini (tree-fuchsia)	*Fuchsia excorticata*, Linn. f.
koromiko	*Hebe salicifolia*, (Forst. f.) Pennell
lacebark (thousand jacket, houhere)	*Hoheria sexstylosa*, Col.
lancewood	*Pseudopanax crassifolium*, (Soland. ex A. Cunn.) C. Koch
leatherwood (leatherleaf)	*Senecio eleagnifolius*, Hook. f.
mahoe (whiteywood, hinahina)	*Melicytus ramiflorus*, Forst.
maire, black	*Olea cunninghamii*, Hook. f.
maire, white	*O. lanceolata*, Hook. f.
mairetawhake	*Eugenia maire*, A. Cunn.
matipo, black (kohuhu)	*Pittosporum tenuifolium*, Banks et Sol. ex Gaertn.
matai (black pine)	*Podocarpus spicatus*, R. Br.

mapau (red matipo)	*Suttonia australis*, A. Rich.
mingimingi	*Cyathodes acerosa*, R. Br., and *Leucopogon fasciculatus*, A. Rich.
miro	*P. ferrugineus*, D. Don
mistletoe	*Elytranthe* sp.
ngaio	*Myoporum laetum*, Forst.
nikau	*Rhopalostylis sapida*, (Sol. ex Forst. f.) H. Wendl. et Drude
passionfruit, native (kohia)	*Tetrapathaea tetrandra*, (Banks & Sol. ex DC) Cheesem.
pate	*Schefflera digitata*, Forst.
peppertree	*Pseudowintera axillaris*, (Raoul) Dandy
pigeonwood	*Hedycarya arborea*, Forst.
pokaka	*Elaeocarpus hookerianus*, Raoul
poroporo (bullibulli)	*Solanum aviculare*, Forst. f.
puka	*Griselinia lucida*, Forst. f.
pukatea	*Laurelia novae-zelandiae*, A. Cunn.
putaputaweta	*Carpodetus serratus*, Forst.
ramarama	*Myrtus bullata*, Sol.
rangiora (wharangi)	*Brachyglottis repanda*, Forst.
raukawa	*Nothopanax edgerleyi*, (Hook. f.) Harms
rata, northern	*Metrosideros robusta*, A. Cunn.
rewarewa (native honeysuckle)	*Knightia excelsa*, R. Br.
ribbonwood, lowland	*Plagianthus betulinus*, A. Cunn.
rimu (red pine)	*Dacrydium cupressinum*, Sol.
rohutu	*Myrtus obcordata*, Hook. f.
supplejack	*Rhipogonum scandens*, Forst.
stinkwood (hupiro)	*Coprosma foetidissima*, J. R. & G. Forst.
tarata (lemonwood, lemon matipo)	*Pittosporum eugenioides*, A. Cunn.
tauhinu (tauwhini)	*Cassinia leptophylla*, R. Br.
tawa	*Beilschmiedia tawa*, Benth. & Hook. f.
teatree, red (manuka, kahikatoa)	*Leptospermum scoparium*, Forst.
teatree, white (kanuka, tall manuka)	*L. ericoides*, A. Rich.
titoki	*Alectryon excelsum*, Gaertn.
toro	*Suttonia salicina*, (Heward) Hook. f.
totara	*Podocarpus totara*, D. Don
tutu	*Coriaria arborea*, Lindsay
wharangi	*Melicope ternata*, Forst.
wineberry (makomako)	*Aristotelia serrata*, (Forst. f.) Oliver

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NOTE ON THE EFFICIENCY OF APHID TRAPPING

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(Received for publication, 10 October 1958)

Summary

From the distribution of numbers of alate aphids of 39 species trapped in Auckland over a period of 12 months the following deductions are made: (1) the sample covered nearly 99·9% of the population (in terms of the species represented in the sample); (2) another sample of the same size, when taken in conjunction with the first, would approximately halve the proportion of the population not represented, and would furnish only 3 or 4 species not already trapped.

The species-individual distribution, in which by trapping or other means repeated samples of a population of insects or animals are collected and a distribution of occurrences of the different species is built up, is of quite considerable statistical interest. The aim of this type of sampling method is to determine, for instance, what and how many species of a certain type of insect are in an area, and their relative abundance, but the distribution can also be used to deduce further information about the uncaught portion of the population. Methods for estimating the population frequency of each species have been developed by Good (1953) and Good and Toulmin (1956), assuming virtually nothing about the underlying population. In particular these authors obtain estimates of the coverage of the sample (i.e., the proportion of the population represented by the species in the sample) and the increase in coverage and numbers of species caught if a second sample is taken.

This note considers some purely statistical aspects of the distribution of trapped aphids recorded in the preceding paper (Lamb, 1958). The total numbers of individuals caught in each species over the year (from Lamb's Table 1) have been fitted to two specific distributions, the logarithmic series (Fisher, Corbet, and Williams, 1943) and the truncated lognormal distribution (a discrete lognormal distribution with the zeros missing). Both these distributions provide excellent fits to the data, as is shown in the table, the second being slightly better on the result of two tests for goodness of fit, the χ^2, and the Kolmogorov-Smirnov. (The latter test is strictly applicable to continuous distribution functions only, but in the present case the large range of the counts (1 to 1304) indicates that continuity can be fairly safely assumed).

No. of individuals per species (r)	Observed no. of species (n_r)	Expected no. of species: Log series	Expected no. of species: Truncated lognormal
1	6	5·9	5·2
2	3	3·0	3·2
3	2	2·0	2·3
4	—	1·5	1·8
5-6	3	2·2	2·7
7-9	4	2·2	2·8
10-15	4	2·9	3·5
16-25	2	2·9	3·4
26-40	3	2·6	2·8
41-60	4	2·2	2·1
61-90	3	2·1	1·9
91-150	—	2·6	2·0
151-250	—	2·3	1·5
251-500	2	2·5	1·5
501-	3	2·2	2·1

Neither of these two theoretical distributions can be regarded as a useful description of the population in the sense of supplying information on the underlying distribution of abundances. R. A. Fisher derived the logarithmic series as a limiting case of the negative binomial series excluding the zero observations. It implies that the number of species is infinite and can therefore never be a true representation of the population although it gives perfectly good fits in a number of cases. Similarly the truncated lognormal distribution gives very good fits (usually to the same data as the logarithmic series), but its appeal has been mainly intuitive and its justification empirical (cf. Preston, 1948). It does give reasonable estimates of the total population of species from which the sample was taken, in cases where there is a check on this (in the present example it gives an estimated total of 55 species, as compared with 56 alate species recorded in New Zealand), but again this sort of statement is purely empirical. Good (1953) finds that a hypothesis on the population frequencies, such as that leading to the logarithmic series, can give a good fit to the numbers n_r but quite the wrong values to other characteristics of the population.

However, Good in his two papers specifies that the n_r should be smoothed before the application of his methods, and the estimates are expressed in terms of smoothed values. Both distributions give efficient graduations of the data, and it is interesting to see how close is the agreement for the population parameters estimated. They are as follows, with (very) approximate standard errors in parentheses:

Type of Smoothing	Logarithmic Series	Truncated Lognormal
Population coverage of sample (%)	99·86 (± 0·05)	99·88 (± 0·05)
Coverage if sample doubled (%)	99·93 (± 0·03)	99·95 (± 0·02)
Number of new species if sample doubled	4·1 (± 2·0)	3·3 (± 1·8)

Hence the conclusions in the summary. From the purely limited viewpoint of the amount of information on species numbers and abundance, it would appear uneconomical to increase the size of the sample.

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CONTRIBUTIONS TO A CHROMOSOME ATLAS OF THE NEW ZEALAND FLORA—1

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Summary

The present paper introduces a series designed to document and illustrate the chromosomes of New Zealand plants. The first contribution deals with 20 endemic species of the Coniferae.

Introduction

When concerned with taxonomic and phylogenetic problems, the plant cytologist can most usefully collaborate with the geneticist and the experimental taxonomist, since all three approaches have a common objective—namely, a *genetic* classification of species and populations. To have meaning for taxonomists and other students of phylogeny, the findings of such a classification must at all times be referable to *voucher* herbarium specimens, preferably of material collected in the wild.

Genetic classification begins with the determination of chromosome number, and at this level can best be summarized in the form of a chromosome atlas, or as contributions thereto which are complete as to genus or family. It is highly desirable, finally, to illustrate the chromosome complements and so give emphasis to their systematic character.

With these requirements in mind, the present series of publications is designed to document and illustrate the chromosome complements of New Zealand plants. As far as possible, each contribution will be complete at the generic level and will provide data for natural hybrids. Illustrations will be of uniform magnification, × 1500. Voucher herbarium specimens will be held at the Botany Division, Department of Scientific and Industrial Research, Christchurch.

The present paper deals with the 20 endemic species of the Coniferae.

TABLE 1.—Documented Chromosome Numbers of New Zealand Plants: The Coniferae.

Species	n	2n	Source	Herb. No.
ARAUCARIACEAE				
Agathis australis Salisb.	13	26	Whangarei	100872
			Botanic Gardens, Christchurch	200251–2
CUPRESSACEAE				
Libocedrus bidwillii Hook. f.	11	22	Botanic Gardens, Christchurch	200152
			Kumara Road, Waimea S.D., Westland	200153
			Fletchers Creek, Reefton Area	200253
L. plumosa (D. Don) Sargent	11	22	Otari Gardens, Wellington	200154
			Blackwater Creek, Hohonu S.D., Westland	200155
			Botanic Gardens, Christchurch	200156
PODOCARPACEAE				
Dacrydium intermedium Kirk	15	30	Cultivated plant, New Plymouth	100827
			Blackwater Creek Area, Hohonu S.D., Westland	200018
			Garvey's Creek, Reefton Area	200209–10
D. laxifolium Hook. f.	15	30	Arthurs Pass, Canterbury	100679
			Arthurs Pass, Canterbury*	200032–5
			Near Homer Tunnel, Otago*	200028
			Boulder Lake, north-west Nelson*	200030
			Stewart Island*	200031
D. biforme (Hook.) Pilger	12	24		
			Mt. Cargill, Dunedin	100737
			Mt. Cargill, Dunedin	200061
			Arthurs Pass, Canterbury	—
			Cultivated plant, New Plymouth	—

D. kirkii F. Muell. ex Parl.	11	22	Cultivated plant, New Plymouth	100625
			Cultivated plant, near Auckland	200066
			Otari Gardens, Wellington	200219
D. bidwillii Hook. f. ex Kirk	9	18	Bell Hill Flat, South-west Nelson	101467
			White River, Canterbury	200043
			Block XI, Mahinapua S.D., Westland	200044–5
			Southland	200047
			Poerua River, Mt One One S.D., Westland	200050–9
			Poerua River, Mt One One S.D., Westland	200206–7
var. ***reclinata*** Kirk	—	18	Broken River, Canterbury*	200060
D. colensoi Hook.	10	20	Reefton District	100612
			Duffers Creek, Westland	100384
			Near Hokitika, Mahinapua S.D., Westland	200005
			Block XI, Mahinapua S.D., Westland	200006
			Otari Gardens, Wellington	200008
D. cupressinum Lamb	10	20	Near Hokitika, Mahinapua S.D., Westland	200009
			Block XI, Mahinapua S.D., Westland	200011
			Botanic Gardens, Christchurch	200013
			Otari, Wellington	200014
			Southland	—
Podocarpus dacrydioides A. Rich.	10	20	Peel Forest, South Canterbury	100267
			Botanic Gardens, Christchurch	200071
			Riccarton Bush, Christchurch	200072
			Blackwater Creek, Hohonu S.D., Westland	200073
			Near Hokitika, Mahinapua S.D., Westland	200074

TABLE 1.—*Continued.*

P. spicatus R. Br. ex Mirbel	19	38	Cultivated plant, New Plymouth	100839
			Blackwater Creek, Hohonu S.D., Westland	200087
			Main South Road, Whataroa S.D., Westland	200088
			Botanic Gardens, Christchurch	200089
			Otari Gardens, Wellington	200090
			Peel Forest, South Canterbury	200093
P. ferrugineus G. Benn. ex D. Don	18	36	Municipal Nurseries, Christchurch	100084
			Lower Pouakai Range, Taranaki	100570
			Botanic Gardens, Christchurch	200076
			Block XV, Waimea S.D., Westland	200077
			Near Dunedin	200079
			Cultivated plant, Riccarton Bush, Christchurch	200255
P. nivalis Hook.	19	38	Arthurs Pass, Canterbury†	200123
			Temple Basin Track, Arthurs Pass, Canterbury	200124
			Otari Gardens, Wellington	200254
var. ***erectus*** Ckn.‡	18	36	Cass River, Canterbury†	200142
			Arthurs Pass, Canterbury*	200133
			Mt Te Moehau, Coromandel*	200137
			Mt. Peel, North-west Nelson*	200138
P. hallii Kirk	17	34	Rimu Forest, near Hokitika	200113
			Rimu Township, Kaniere S.D., Westland	200118
			Near above locality	200139
			Blackwater Creek, Hohonu S.D., Westland	200016–7
			Near Dunedin	200140
			Warwick South, Maruia District, Nelson	200134
			Aorere River, North-west Nelson	200136

P. totara G. Benn. ex D. Don	17	34	Peel Forest, South Canterbury	100616
			Peel Forest, South Canterbury	200128–9
			Peel Forest, South Canterbury	200131
			Otari, Wellington	200132
			Waipoua, Auckland	200135
P. acutifolius Kirk	17	34	Blackwater Creek, Hohonu S.D., Westland	200097–8
			Ruatapu, near Hokitika	200101
			Evans Creek, Westland	200102
			Botanic Gardens, Christchurch	200104
			Near Maruia, Nelson	200105–6
Phyllocladus alpinus Hook. f.	9	18	Arthurs Pass, Canterbury	200143
			Botanic Gardens, Christchurch	200144
			Otari Gardens, Wellington	200145
			Blackwater Creek, Hohonu S.D., Westland	200146
P. glaucus Carr.	9	18	Botanic Gardens, Christchurch	200147
			Otari Gardens, Wellington	200256
P. trichomanoides D. Don	9	18	Omanawa River, Kaimai Range, Bay of Plenty	100584
			Botanic Gardens, Christchurch	200148
			Otari Gardens, Wellington	200150

*Grown on at Otari Gardens, Wellington.

†Grown on at Botanic Gardens, Christchurch.

‡Natural hybrids between *P. nivalis* and *P. hallii*.

3

4

FIGS 1 to 8.—First Metaphase of Meiosis. × 1500.

FIG. 1.—*Agathis australis* (n = 13), 13^{II}. See Figs 24, 25.

FIG. 2.—*Libocedrus plumosa* (n = 11), 11^{II}.

FIG. 3.—*Phyllocladus alpinus* (n = 9), 9^{II}.

FIG. 4.—*P. glaucus* (n = 9), 9^{II}. See Fig. 26.

FIG. 5.—*Podocarpus nivalis* (n = 19), 19^{II}.

FIG. 6.—*P. nivalis* var. *erectus* (n = 18), 2^{III} 15^{II}

FIG. 7.—*P. acutifolius* (n = 17), 17^{II}.

FIG. 8.—*P. spicatus* (n = 19), 19^{II}.

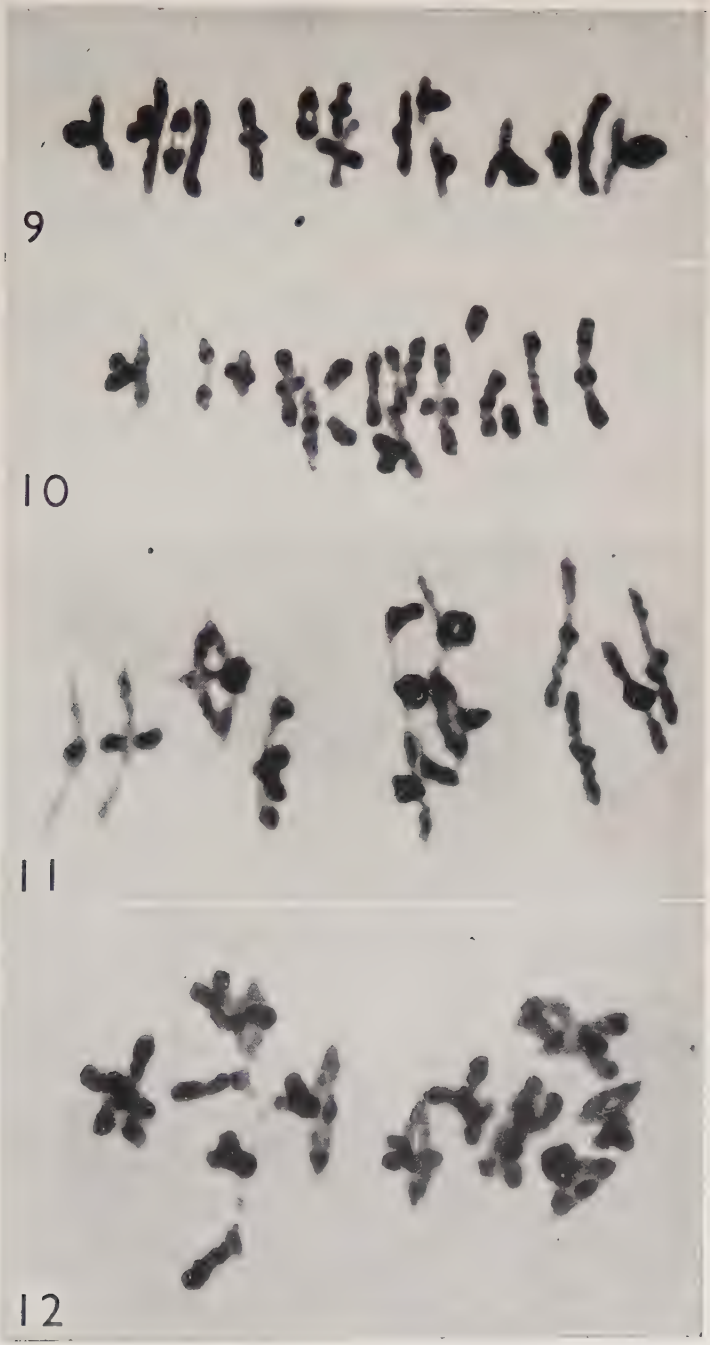
FIGS 9 to 12.—First Metaphase of Meiosis. × 1500.

FIG. 9.—*Dacrydium laxifolium* (n = 15), 15^{II}.

FIG. 10.—*D. intermedium* (n = 15), 15^{II}.

FIG. 11.—*D. biforme* (n = 12), 2^{II}.

FIG. 12.—*D. colensoi* (n = 10), 10^{II}.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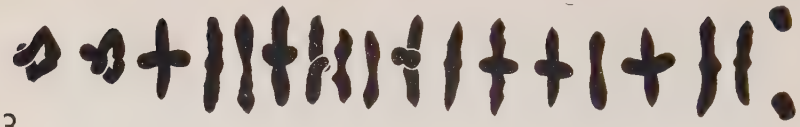

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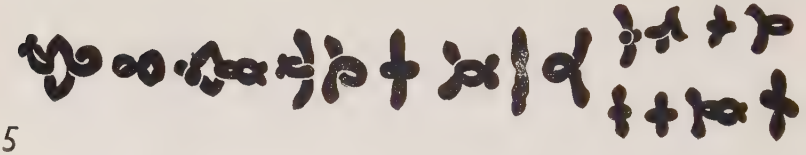

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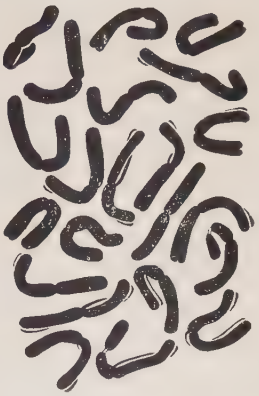

FIGS 13 to 21.—First Metaphase of Meiosis. × 1500.

FIG. 13.—*Podocarpus ferrugineus* (n = 18), 18^{II}. FIG. 14.—*P. hallii* (n = 17), 17^{II}. FIG. 15.—*P. totara* (n = 17), 17^{II}. FIG. 16.—*P. dacrydioides* (n = 10), 10^{II}. FIG. 17.—*Dacrydium cupressinum* (n = 10), 10^{II}. FIG. 18.—*D. kirkii* (n = 11), 11^{II}. FIG. 19.—*D. bidwillii* (n = 9), 9^{II}. FIG. 20.—*Phyllocladus trichomanoides* (n = 9), 9^{II}. FIG. 21.—*Libocedrus bidwillii* (n = 11), 11^{II}.

FIGS 22 to 26.—Metaphase of Mitosis. × 1500.

FIG. 22.—*L. bidwillii* (2n = 22). FIG. 23.—*L. bidwillii*, chromosome idiogram. FIG. 24.—*Agathis australis* (2n = 26). FIG. 25.—*A. australis*, chromosome idiogram. FIG. 26.—*Phyllocladus glaucus* (2n = 18).

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The authors would like to emphasize the fact that the completion of this study would have been quite impossible without the assistance noted.

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